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ALEXANDER L. HOLLEY.....Jan. 29, 1882.
ERASTUS W. SMITH.....June 12, 1882.
PETER COOPER, Honorary Member.....April 4, 1883.
JAMES PARK, JR.....April 21, 1883.
W. K. SEAMAN.....July 2, 1883.
REDMOND J. BROUGH.....July 21, 1883.
SIEMENS, C. W. Honorary Member.....Nov. 20, 1883.

RULES

OF THE

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

OBJECTS.

ART. 1. The objects of the AMERICAN SOCIETY OF MECHANICAL ENGINEERS are to promote the Arts and Sciences connected with Engineering and Mechanical Construction, by means of meetings for social intercourse and the reading and discussion of professional papers, and to circulate, by means of publication among its members, the information thus obtained.

MEMBERSHIP.

ART. 2. The Society shall consist of Members, Honorary Members, Associates and Juniors.

ART. 3. Mechanical, Civil, Military, Mining, Metallurgical and Naval Engineers and Architects may be candidates for membership in this Society.

ART. 4. To be eligible as a *Member*, the candidate must have been so connected with some of the above specified professions as to be considered, in the opinion of the Council, competent to take charge of work in his department, either as a designer or constructor, or else have been connected with the same as a teacher.

ART. 5. *Honorary Members*, not exceeding twenty-five in number, may be elected. They must be persons of acknowledged professional eminence, who have virtually retired from practice.

ART. 6. To be eligible as an *Associate*, the candidate must have such a knowledge of, or connection with, applied science, as qualifies him, in the opinion of the Council, to co-operate with engineers in the advancement of professional knowledge.

ART. 7. To be eligible as a *Junior*, the candidate must have been in the practice of engineering for at least two years, or he must be a graduate of an engineering school.

The term "Junior" applies to the professional experience, and not to the age of the candidate. Juniors may become eligible to Membership.

ART. 8. All Members and Associates shall be equally entitled to the privileges of Membership, provided that Honorary Members who are not also Members or Associates and Juniors shall not be entitled to vote nor to be members of the Council.

ELECTION OF MEMBERS.

ART. 9. All candidates for admission to the Society, excepting candidates for honorary membership, must be proposed by at least three members, or members and associates, to whom they must be personally known, and be seconded by two others; the proposal to be accompanied by a statement in writing of the grounds of their application for election, including an account of their professional service.

ART. 10. All such applications and proposals received by the Council, up to thirty days before a regular meeting, shall, at least twenty days before such regular meeting be passed upon by the Council. The Secretary shall, at least twenty days before such regular meeting, mail to each member and associate, in the form of a letter ballot, the names of candidates recommended by the Council for election.

ART. 11. Any member or associate entitled to vote may erase the name of any candidate and return to the secretary such ballot inclosed in two envelopes, the inner one to be blank and the outer one to be indorsed by the voter.

ART. 12. The rejection of any candidate for admission as member, associate, or junior, by *seven* voters, shall defeat the election of said candidate. The rejection of any candidate for admission as honorary member by *three* voters shall defeat the election of said candidate.

ART. 13. The said blank envelopes shall be opened by the Council at any meeting thereof, and the names of the candidates elected shall be announced in the first ensuing meeting of the Society, and also in the first ensuing list of members. The names of candidates not elected shall neither be announced nor recorded in the proceedings.

ART. 14. Candidates for admission as honorary members shall not be required to present their claims; those making the nominations shall state the grounds therefor, and shall certify that the

nominee will accept if elected. The method of election in other respects shall be the same as in case of other candidates.

ART. 15. All persons elected to the Society, excepting honorary members, must subscribe to the rules and pay to the Treasurer the entrance fee and yearly dues before they can receive certificates of membership. If this is not done within six months of notification of election, the election shall be void.

ART. 16. The proposers of any rejected candidate may, within three months after such rejection, lay before the Council written evidence that an error was then made, and if a reconsideration is granted, another ballot shall be ordered.

ART. 17. The Council shall pass upon applications of juniors for membership, and shall order ballots upon such recommendations, in the manner hereinbefore described.

FEES AND DUES.

ART. 18. The initiation fee of members and associates shall be $15, and their annual dues shall be $10, payable in advance at the annual meeting; *provided*, that the persons elected at the meeting following the annual meeting shall pay $8, and persons elected at the meeting preceding the annual meeting shall pay $4, as dues for the current year. The initiation fee of juniors shall be $10, and their annual dues shall be $5, payable in advance. Any member or associate may become, by the payment of $150 at any one time, a life member or associate, and shall not be liable thereafter to annual dues.

ART. 19. Any member, associate, or junior in arrears may, at the discretion of the Council, be deprived of the receipt of publications, or stricken from the list of members, when in arrears for one year; *provided*, that such person may be restored to membership by the Council on payment of all arrears, or by re-election after an interval of three years.

OFFICERS.

ART. 20. The affairs of the Society shall be managed by a Council, consisting of a President, six Vice-Presidents, nine Managers, and a Treasurer, who shall be elected from among the members and associates of the Society at the annual meetings, to hold office as follows:

ART. 21. The President and the Treasurer for one year; and no person shall be eligible for immediate re-election as President who shall have held that office, subsequent to the adoption of these

rules, for two consecutive years; the Vice-Presidents for two years, and the Managers for three years; and no Vice-President or Manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected. *Provided* that, at the meeting for organization, the entire board of elective officers and managers shall be chosen, of whom the President, the Treasurer, three Vice-Presidents, and three Managers shall serve until the first Thursday of November, 1881; three Vice-Presidents and three Managers shall serve until the first Thursday of November, 1882, and three Managers shall serve until the first Thursday of November, 1883. The holding for the several terms shall be determined by lot among them.

ART. 22. A Secretary, who may or may not be a member of the Society, shall be appointed for one year by a majority of the members of the Council at its first meeting after the annual election, or as soon thereafter as the votes of a majority of the members of the Council can be secured for a candidate. The Secretary may be removed by a vote of twelve members of the Council, at any time after one month's notice has been given him by a majority of its members to show cause why he should not be removed, and he has been heard to that effect. The Secretary may take part in any of the deliberations of the Council, but, if not a member of the Society, shall not have a vote therein. His salary shall be fixed for the time he is appointed by a majority vote of the Council.

ART. 23. At each annual meeting after the first, a President, three Vice-Presidents, three Managers, and a Treasurer shall be elected, and the term of office shall continue until the adjournment of the meeting at which their successors are elected.

ART. 24. The duties of all officers shall be such as usually pertain to their offices or may be delegated to them by the Council or the Society; and the Council may, in its discretion, require bonds to be given by the Treasurer. At each annual meeting the Council shall make a report of proceedings to the Society, together with a financial statement.

ART. 25. Vacancies in the Council may occur by death or resignation; or the Council may, by vote of a majority of all its members, declare the place of any officer vacant, on his failure for one year, from inability or otherwise, to attend the Council meetings or perform the duties of his office. All vacancies shall be filled by the appointment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor

was elected or appointed; *provided*, that the said appointment shall not render him ineligible at the next annual meeting.

ART. 26. Five members of the Council shall constitute a quorum; but the Council may appoint an Executive Committee, or business may be transacted at a regularly called meeting of the Council, at which less than a quorum is present, subject to the approval of a majority of the Council, subsequently given in writing to the Secretary and recorded by him with the minutes.

ART. 27. No bill shall be paid for the Society, until it has been certified by the person authorized to contract it, and audited by committee on finance.

ELECTION OF OFFICERS.

ART. 28. At the regular meeting preceding the annual meeting, a nominating committee of five members, not officers of the Society, shall be appointed, and this committee shall, at least thirty days before the annual meeting, send the names of nominees to the Secretary, who shall at once mail the said list of names to each member and associate, in the form of a letter ballot.

ART. 29. In the election of Vice-Presidents, each member and associate may cast as many votes as there are Vice-Presidents to be elected. He may give all these votes to one candidate, or distribute them among more, as he chooses. Managers shall be voted for in the same way.

ART. 30. Any member or associate entitled to vote may vote by retaining or changing the names on said list, leaving names not exceeding in number the officers to be elected, and returning the list to the Secretary—such ballot inclosed in two envelopes, the inner one to be blank and the outer one to be indorsed by the voter. *Provided*, that no member or associate in arrears since the last annual meeting shall be allowed to vote until said arrears shall have been paid.

ART. 31. The said blank envelopes shall be opened by tellers at the annual meeting, and the person who shall have received the greatest number of votes for the several offices shall be declared elected.

MEETINGS.

ART. 32. The annual meeting of the Society shall be held in the City of New York, on the first Thursday in November, at which a report of the proceedings of the Society and an abstract of the accounts shall be furnished by the Council; the Council may

change the time of the annual meeting, and shall, in that case, give six months' notice to members and associates.

ART. 33. Two other regular meetings of the Society shall be held in each year, at such times and places as the Council may appoint. At least thirty days' notice of such meetings shall be mailed by the Secretary to members, honorary members, associates and juniors.

ART. 34. Special meetings may be called whenever the Council may see fit; and the Secretary shall call a special meeting at the written request of twenty or more members. The notices for special meetings shall state the business to be transacted, and no other shall be entertained.

ART. 35. Any member, honorary member or associate may introduce a stranger to any meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

ART. 36. Every question which shall come before the Society shall be decided, unless otherwise provided by these rules, by the votes of a majority of the members and associates present, provided there is a quorum.

ART. 37. At any regular meeting of the Society, thirteen or more members and associates shall constitute a quorum.

ART. 38. The Council shall have power to decide on the propriety of communicating to the Society any paper which may be received, or to refer it back to its author for revision or amendment; also, to decide which of the papers read before the Society shall be printed in the *Transactions*. Before such paper appears in the *Transactions* of the Society, a revised proof of the paper and discussion shall be sent by the Secretary to the author, and, so far as practicable, to every member taking part in the discussion, with request that they call attention to any errors therein. When the Council shall so direct, printed copies of papers shall be distributed to the membership in advance of the meeting at which they are to be presented and discussed.

ART. 39. Intimation, when practicable, shall be given at a general meeting, of the subject of the paper or papers to be read, and of the questions for discussion at the next meeting.

ART. 40. The Society shall claim no exclusive copyright in papers read at its meetings, nor in reports of discussions, except in the matter of official publication with the Society's imprint, as its *Transactions*. The Secretary shall have sole possession of papers between the time of their acceptance by the Council and their reading, together with the drawings illustrating the same; and at the

time of such reading, or as soon thereafter as practicable, he shall have printed copies of such papers "subject to revision," with such illustrations as are needed for the *Transactions*, for distribution to the members and for the use of technical newspapers, American and foreign, which may desire to reprint them in whole or in part. The policy of the Society in this matter shall be to give papers read before it the widest currency possible, with a view to making the work of the Society known, encouraging mechanical progress and extending the professional reputation of its members.

ART. 41. The author of each paper read before the Society shall be entitled to twelve copies, if printed, for his own use, and shall have the right to order any number of copies at the cost of paper and printing; *provided*, that said copies are not intended for sale.

ART. 42. The Society is not, as a body, responsible for the statements of fact or opinion, advanced in papers or discussions, at its meetings; and it is understood that papers and discussions should not include matters relating to politics or purely to trade.

AMENDMENTS.

ART. 43. These rules may be amended, at any annual meeting, by a two-thirds vote of the members present; *provided*, that written notice of the proposed amendment shall have been given at a previous meeting.

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PAPERS

OF THE

NEW YORK MEETING, 1882.

PROCEEDINGS

OF THE

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

PROCEEDINGS OF THE NEW YORK MEETING, NOVEMBER, 1882.

COMMITTEES OF ARRANGEMENT.

Local.—Prof. W. P. TROWBRIDGE, *Chairman;* F. B. Allen, S. W. Baldwin, J. C. Bayles, A. W. Colwell, C. W. Copeland, C. H. Loring, W. C. Hicks, C. W. Nason, W. H. Weightman, H. B. Miller, F. M. Wheeler, W. H. Wiley, A. Vanderbilt, C. C. Worthington, H. S. Hayward, S. McElroy, W. E. Ward, T. W. Rae, G. H. Robinson, G. H. Reynolds.

Executive.—Messrs. Copeland, Rae, Wiley.

Invitations and Receptions.—Messrs. Trowbridge, Bayles, Loring.

Excursions.—Messrs. Hayward, Loring, Worthington.

Hotel and Accommodation.—Messrs. Weightman, Vanderbilt, Wheeler.

Rooms and Places of Meeting.—Messrs. Ward, Nason, Rae.

Printing and Press Notices.—Messrs. Hicks, Rae, Miller.

THE regular Annual Meeting of 1882 was opened by a Joint Session of the American Society of Mechanical Engineers with the American Society of Civil Engineers and the American Institute of Mining Engineers. The special session was called to listen to a Memorial Address in commemoration of Alexander Lyman Holley, and was held in the Turf Club Theater, at eight o'clock, on November 1st, 1882. On the stage with the President and the orator of the evening were Ex-Governor Holley, Mr. J. J. R. Croes, and Gen. G. S. Greene; Vice-Presidents Coxe and Trowbridge, and Secretaries Bogart, Drown, and Rae.

President Thurston, after calling the Convention to order, said:

It is not necessary that the Chair should state in detail the *raisons d'être* of this meeting. It is enough to say that the three great national societies of engineers, the American Society of Civil Engineers, the American Institute of Mining Engineers, and the

American Society of Mechanical Engineers, have gathered here to-night, at the close of All Saints' Day, on the eve of All Souls' Day, on that feast day, "of holy days the crest," as Lowell calls it, to do honor to a common colleague and a mutual friend, who has "gone before." We meet to honor, not "the *unknown* good who rest in God's still memory folded deep," but one whose great work is known of all, men and angels, who, as a man of genius, stood eminent among his fellows, and who, as a benefactor of his kind, stands preëminent in his day and generation—one whose good works shall endure through all time, and shall be more and more fruitful of blessings to mankind to the end.

And while we meet to do honor to his memory as one of the brightest ornaments of our noble profession, as a distinguished member of these societies, as an earnest co-worker in all plans that affected their prosperity, we feel that the heart is vastly more concerned than the head, and we would still more highly honor his memory as one whose superlative merit in his profession was eclipsed by the beauty of his personal character. We commemorate the loss, in him, of a beloved colleague and a never to-be-forgotten friend.

The committee, in arranging the ceremonies of this evening, have been peculiarly fortunate in being able to secure as the orator of the occasion the gentleman whom I now have the pleasure and the honor to present to you. On this evening, if on any evening of the year, we may hope and believe that our friend is permitted to be with us, and we may feel well assured that his spirit will find a perfect satisfaction in the choice which has been made. It will afford us all very great pleasure to be able to listen to the story of a life full of earnest strivings, of honest fealty to duty, of noble loyalty to friends, of a life full of good work and crowned with great successes, short though it was, from one who is so well fitted to comprehend, to appreciate, and to describe his work, from one who long worked hand in hand with him and at some of his greatest tasks, and especially from one who for many years was bound to him by the ties of a hardly less than fraternal love. Such a speaker needs not the powers of the orator. A plain, straightforward story on such an occasion and from such a narrator is highest eloquence.

I have the honor and the pleasure to present to the Convention Dr. Rossiter Worthington Raymond.

Dr. Raymond then delivered an abridgment of the Memorial

Address in commemoration of Alexander Lyman Holley, which appears in the Papers of the New York Meeting.

At the close of the oration, Mr. Bayles rose:

Mr. Bayles.—After such an address as that to which we have listened, this audience is in no mood for other remarks, and with a view to terminating this meeting properly, I would offer this resolution:

Resolved, That we tender our thanks to Dr. R. W. Raymond for his eloquent and instructive address, and for the labor which has enabled him to bring together so many facts which better aid us in appreciating the beautiful and symmetrical personal character of Alexander Lyman Holley, and in valuing his varied and conscientious work as an engineer.

The resolution was seconded by Mr. Fritz, and adopted unanimously.

On motion the joint session adjourned.

MORNING SESSION.

November 2d, 1882.

The annual meeting of the American Society of Mechanical Engineers was called to order in the Turf Club Theater, New York City, at 10 A.M., on Thursday, November 2d, by the President.

The following members were in attendance:

A. Vanderbilt	New York City.
Frederick M. Wheeler	New York City.
Charles Sperry	Westbrook, Conn.
William K. Seaman	Scranton, Pa.
C. E. Billings	Hartford, Conn.
T. L. Churchill	Boston, Mass.
H. S. Hayward	Jersey City, N. J.
O. P. Remick	Newport, R. I.
W. Barnet Le Van	Philadelphia, Pa.
J. J. Illingworth	Utica, N. Y.
C. C. Collins	Erie, Pa.
E. H. Parks	Providence, R. I.
George H. Smith	Providence, R. I.
A. Faber Du Faur	New York City.
Moses G. Wilder	Philadelphia, Pa.
E. F. C. Davis	Pottsville, Pa.
George M. Bond	Hartford, Conn.
Charles P. Deane	Holyoke, Mass.
George H. Barrus	Boston, Mass.
S. W. Robinson	Columbus, O.
F. B. Allen	New York City.
A. C. Hobbs	Bridgeport, Conn.

W. F. Durfee	Bridgeport, Conn.
William H. Harrison	Braintree, Mass.
James E. Denton	Hoboken, N. J.
J. F. Holloway	Cleveland, O.
Thos. R. Almond	Brooklyn, N. Y.
Gaetano Lanza	Boston, Mass.
F. R. Hutton	New York City.
Albert Stearns	Brooklyn, N. Y.
Lewis F. Lyne	New York City.
Lycurgus B. Moore	New York City.
Jackson Bailey	New York City.
Horace B. Miller	New York City.
C. J. H. Woodbury	Boston, Mass.
William Cleveland Hicks	New York City.
William H. Weightman	New York City.
Alfred R. Wolff	New York City.
R. H. Thurston	Hoboken, N. J.
J. Sellers Bancroft	Philadelphia, Pa.
S. H. Finch	New York City.
William J. Baldwin	New York City.
Oberlin Smith	Bridgeton, N. J.
Thomas R. Pickering	Portland, Conn.
J. C. Bayles	New York City.
Alfred Colin	New York City.
A. Miller	New York City.
H. C. Jones	Wilmington, Del.
H. A. Hill	Boston, Mass.
William J. Root	Brooklyn, N. Y.
Thomas Whiteside Rae	New York City.
William P. Trowbridge	New York City.
Joshua Rose	New York City.
William E. Partridge	New York City.
W. G. Cartwright	Hoboken, N. J.
J. Burkitt Webb	Ithaca, N. Y.
C. Kirchoff, Jr.	New York City.
Thomas Egleston	New York City.

On motion of Mr. Durfee it was agreed to dispense with the reading of the minutes of the last meeting, and to accept them as recorded.

The President.—The first thing to be taken up in the order of business will be the counting of the ballots for new members. How will you have them counted?

Prof. J. Sweet.—I move that the chairman appoint tellers, and that the tellers report as soon as possible.

The motion being seconded and carried, the President appointed Mr. Franklin B. Allen as first teller, and requested him to select two gentlemen to assist him in this duty.

The President.—The next action in the order of business should be a report from the Council in regard to the general condition of the Society. A Council meeting was to have been held this morning; but the early meeting of the Society, and the fact that members do not come in promptly would prevent our having a quorum. I can say, however, all that need be said in the matter. The Society has increased in membership since the first of the year just closed, from 297 to 354, if we include those balloted for to-day. During the year the Secretary has issued Volume II. of the Transactions, and it has been sent out to members. The papers of the last meeting were to have been sent in by the printers to-day, and the Secretary expects them every moment. The report of the Treasurer lies before me, and I will ask the Secretary to read it.

The Secretary then read the Treasurer's report as follows:

TREASURER'S REPORT.

NEW YORK, November 1, 1882.

To the American Society of Mechanical Engineers:

GENTLEMEN:—I have the honor to submit the second annual report of the finances of the Society, which extends from my acceptance of the office of Treasurer on December 7, 1881, to the present date.

Receipts have been as follows:

Transfer from past Treasurer, December 7, 1881, in cash	$1,178 08
Transfer from past Treasurer, December 7, 1881, petty cash	25 00
Life membership	150 00
Initiation fees	445 00
Annual dues	2,624 13
Badges	404 54
Interest on United States Bonds	60 00
Sale United States Bonds face value $1,000 cost	1,138 75
Premium on ditto	61 25
Paper sales	9 15
Total	$6,095 90

Payments as follows:

Engraving	$358 12
Traveling	6 36
General expenses	648 25
Salary	1,696 97
Printing and stationery	1,887 39
Postage	417 23
Badges	1,074 00
Total	$6,088 32

thus leaving on hand a balance at this date in bank of $7.58.

In addition to the above cash receipts from the past Treasurer, there was also placed in my hands, as an invested fund of the Society, two 4 per cent. United States Government bonds of the face value of $1,000 each. All the payments made were upon the audit of the bills and vouchers by the Finance Committee according to the rules of the Society.

On account of accumulated indebtedness against the Society on August 7, and to the want of sufficient funds in bank at the time to pay these bills, I considered it to the interest of the Society to sell one of the United States Government bonds to procure the necessary funds to sustain the credit of the Society. This I did. From its disposal I received $1,200, being a premium of $61.25 above the cost. This leaves in my hands at this date but one of the above-mentioned United States Government bonds, and which is held as an invested fund.

There is at the present time due from membership $376.31, as follows:

For initiation fees	$30 00
For annual dues	285 45
For badges	60 86
Total	$376 31

There are in my hands at this time duly audited bills by the Finance Committee amounting to $57 for printing, which, for the want of ready funds, still remain unpaid. I am also informed that there is a bill amounting to $988 in the hands of the Secretary of this Society for printing, ready to be audited by the Finance Committee when the funds are available for its payment. There are in addition due the Secretary one month's salary for services for the month of October, as well as three months' clerk hire for the Treasurer, these amounting to $200.

It seems not to be well understood by some members of the Society that the annual dues are payable at the commencement of the Society's year, namely, in November, commencing the year, and it is probably for this reason that the dues of so many of the members remain unpaid, they supposing them payable at the end of the year. If this was clearly understood by all the membership the dues would undoubtedly be more promptly paid.

The total amount of receipts from all items of membership for the last year, if all accounts had been closed, would have been $3,692, and the total expenditures for the same period being

$6,088.32, shows an amount of $2,396.32 expended more than the total amount receivable from all sources of membership during the past year.

Respectfully submitted,
CHARLES W. COPELAND, *Treasurer.*

The President.—I would say in regard to this matter of finance, that it is the most critical matter which the Society will have to attend to during the coming two years. Our expenses have exceeded our current receipts. The fact is due partly to the expenditure which has been made in the publication of papers and partly to the circumstance that a good deal of the previous year's work was paid for during the past year.

Balancing accounts as well as I can, comparing the current receipts from membership dues with the necessary expenses, it looks as if they would just about balance, assuming that we print our transactions as we have done heretofore. The result has been this year the production of a volume of considerable size, and on the whole I think of considerable value to the members. But during the coming year it is proper that some course should be taken to limit expenditures, and at the last Council meeting a plan was talked over of making appropriations based upon the current receipts simply, and the receipts not of the current year but of the previous year. That is to say, our receipts last year were about $3,600, and during the coming year the idea would be to pay one-third of that amount to the Publication Committee, and limit the amount of expenditure to that sum. Then, basing our appropriations in that way and leaving a large margin for incidental expenses, it would place the Society in such shape that it never could become bankrupt. I imagine that when the newly-elected officers have taken their seats, their first duty will be to adjust some such plan and arrange with the Finance Committee for its adoption, so that no appropriations shall be made that are not fully within the line within which the Society is to work. I should say of my own judgment that the publication of papers during the coming year will be considerably restricted, and that we shall not issue as many papers as during the past. Incidental expenditures have been considerable, as they naturally would be in starting a new work like this; but how far they can be restricted in future it is impossible for me to say. I have no doubt, however, that if we find difficulty in doing the work we have to do with the funds coming in from dues, we shall find members willing

to make a little balance for us. Among the schemes in hand is one that the Publication Committee and the Finance Committee shall constitute themselves a committee of solicitation in the hope of getting a large publication fund. If any member has any suggestions to make in regard to the matter they can be presented here orally or sent in writing to the Council.

Reports from committees are in order. We have one very important committee to report this session. Is any member of the Committee on Gauges present?

A Member.—The report is prepared, but has not yet been submitted to the committee. They have called a meeting for this afternoon after the close of the afternoon session.

The President.—If it suits the gentleman, I will say then that the meeting of the Gauge Committee occurs at five o'clock, for the purpose of completing that committee's report, and we hope to have it before us at our next business meeting.

Is any report to be presented by the Committee on the Holley Memorial? Can Mr. Bayles tell us anything about that?

Mr. Bayles.—The committees of the three societies met last evening after the close of Dr. Raymond's lecture, and it was then announced unofficially, the Secretary not being present, that the subscriptions had somewhat exceeded $7,000 at that time—I believe about $7,500—and it was suggested to me that I had better mention in the meeting of this Society that the Treasurer would be very glad to receive small subscriptions, and that those who have held back, as many of us have, until gentlemen of wealth who desired to lead in this matter had made their subscriptions, can now make such contributions as they wish. Small subscriptions—of five dollars, or twenty-five dollars, or any other amount that pleases members—will be very acceptable. These subscriptions may be sent to Mr. Charles McDonald, 50 Wall Street, or to any member of the committee.

The President.—We have one or two amendments to the by-laws presented to be voted on at this meeting. We are ready to hear them and take action upon them.

The Secretary read the following amendment:

"*Resolved*, That Article XXVI. of the rules be amended so as to erase the word, 'Five members of the Council shall constitute a quorum, but,' and allow Article XXVI. to commence with the words: 'The Council may appoint,'" etc.

The Secretary.—I would ask that this be passed over to the fol-

lowing meeting, as I wish to submit a further amendment to this, due to some information I have received from a legal authority in regard to it. I was informed that by the law under which we are incorporated, the number of trustees, or the management, may not exceed thirteen. The object of the amendment just read was to bring our rules into strict conformity with the laws of the State, which say that a quorum shall be a majority of the governing body. Our rules prescribe that five shall be a quorum, and our governing body numbers seventeen. There is a lack of consistency here, and, of course, our rules ought to be in strict conformity with the laws of the State under which we are incorporated. I am also advised that our governing body may not, by the same law, exceed thirteen. It numbers seventeen. I learned this only yesterday, and I wish to modify the amendment so as to bring it into accord with the law on that point also. This can be done only by action of the council, so that I am not prepared to submit the amendment to-day.

Mr. Le Van.—Can it go over a year? According to our by-laws all amendments must be made a year in advance. Now the question arises, does not the amendment now proposed put us forward another year?

The President.—If not passed on at this meeting it goes over for another year.

Prof. Hutton.—I move that the matter be laid on the table, in order that the Secretary may present it to the council, so that he can bring it before the meeting, and that our By-Laws may be brought into conformity with the laws of the State.

Agreed to.

The Secretary.—The following amendment was offered by Mr. Bayles:

"Article XL. to read: 'The Society shall claim no exclusive copyright in papers read at its meetings, or in reports of discussions thereon, except in the matter of official publication with the Society's imprint as its transactions. The Secretary shall have sole possession of papers between the time of their acceptance by the Council and their reading, together with the drawings illustrating the same; and at the time of said reading he shall have printed copies for distribution to members present, and shall give the same to representatives of such newspapers as desire them for unofficial publication in whole or part. Copies of the drawings shall at the same time be furnished to journals which have previously made application for them, at the cost of making such copies; *Provided*, that the author of a paper shall in no case be deprived of his right to give copies of the same to any one he chooses, before it is read, or afterward; but if such paper is published unofficially prior to the meeting at which it is to be read, it

shall be considered as withdrawn by the author, and shall not be presented for reading or discussion as a paper of the Society.' "

The Secretary.—This was further amended at the same session by interpolating the words, "with the author's consent." Mr. Bayles also offered an amendment by substitution, as follows:

"Article XL. to read: 'The Society shall claim no exclusive copyright in papers read at the meetings, nor in reports of discussions, except in the matter of official publication, with the Society's imprint, as its transactions. The Secretary shall have sole possession of papers between the time of their acceptance by the Council and their reading, together with the drawings illustrating the same; and at the time of such reading, or as soon thereafter as practicable, he shall have printed copies of such papers, "subject to revision," with such illustrations as are needed for the transactions, for distribution to the members, and for the use of technical newspapers, American and foreign, which may desire to reprint them in whole or in part. The policy of the Society in this matter shall be to give papers read before it the widest currency possible, with a view to making the work of the Society known, encouraging mechanical progress, and extending the professional reputation of its members.' "

The President.—Is the seconder of the original motion present?

Mr. Durfee.—If this is the amendment offered at Altoona, I was the seconder. I accept the amendment.

The amendment was adopted.

The Secretary.—Mr. Le Van offered the following resolution:

"*Resolved*, That each paper intended for presentation and discussion at any meeting of this Society shall, if it pass the Council, be printed with suitable illustrations, 'subject to revision,' and mailed to each member at least six weeks prior to the meeting for which it is intended, and shall also be distributed at said meeting, at which it shall be read by title *only*. Discussions thereon shall then be in order; discussions to be stenographically reported and appended to the revised copy of the paper, which revised copy, with the report of the discussion, shall constitute the authorized edition of the paper, and shall be part of the published *transactions* of the society."

Mr. Bayles.—I merely call attention to the fact that this amendment is in conflict with the one passed which provides that the Secretary shall, *if he can*, print papers before the meeting, or as soon thereafter as possible. I think the resolution just passed anticipates this entirely.

Mr. Le Van.—My resolution says they *must* be printed. The other does not. The great trouble is that no one can carry the paper in his memory after merely hearing it read, and discuss it properly. My object in having them printed in advance was that any one could discuss them. The discussion is the kernel.

Mr. Durfee.—In order to make such a proposition feasible, you will have to pass a resolution compelling every member to print his paper.

Mr. Weightman.—Does this amendment provide for discussion by the Publication Committee as to whether a paper shall be read or published?

The President.—Yes; a resolution of the Council covers that.

Mr. Weightman.—Should not the Publication Committee be brought in there? Because all papers are referred to them first, and from them they go to the Council.

The President.—The Society, however, knows nothing about the Publication Committee. It is a committee formed by the Council to further its own work.

Mr. Rae.—I can simply reiterate the objection which Mr. Bayles makes, that this would have excluded almost all our papers. The experience has been that papers are not submitted until within a few days of the meeting. Our membership is composed of busy men who cannot say with any positiveness that they will be able to present a paper, and all are very chary about saying that they will furnish one at a specific time. Such a rule as this would have excluded nine-tenths of the papers which have been read. I get a conditional promise, and perhaps a day or two in advance of the meeting a paper will be submitted. I would say that only one paper would be brought forward at this meeting if such a rule as Mr. Le Van's amendment contemplates were in force.

Mr. Le Van.—Would it not be better for one good paper to be read than for several to be read which we are not able to discuss?

Mr. Durfee.—I think Mr. Le Van's objection is amply covered by the practice the Society has thus far followed; that is, taking up the papers read at previous meetings and re-discussing them. I think in the programme of this very meeting there is some provision of the kind. Any gentleman who wishes to prepare himself for discussing any particular point has ample opportunity to do so.

Mr. Le Van.—That is like reading last month's news.

Mr. Weightman.—I believe I understood Mr. Le Van to say that the very point of his amendment was that these papers would not be read, but only the discussion would take place. I think the gentleman will find that very few papers will be read outside the meeting. I would like to ask how many of the published papers he or any other member has read outside the meeting at which they were placed before the Society. I have not read one straight through,

and I think the majority of the members will say about the same The mere hearing of the paper read will start a little discussion, while if it is only placed before the Society to read, I am afraid it will fall to the ground.

Mr. Alden.—I would like to ask if six weeks is not a longer time than is necessary in order to have the papers in the hands of the members. I suppose this contemplates that they should be in the hands of members and studied before they are discussed here. A regulation to send them to the committee at least one week before the meeting would not seem so severe.

Mr. Le Van.—My object in stating six weeks is merely to give the Secretary time.

The President.—In answer to the gentleman's question, I would say that, observing the working of the thing, I should conclude that we shall be compelled to allow the members to do about as they do at present—to get their papers in if they are ready, and if not, to let them go over. The drawing of a line is likely to produce some embarrassment. The law of the survival of the fittest would lead no doubt to the presentation of very valuable papers ultimately and to the killing out of those which are not of so much value. I should only say, as a matter of observation simply, that it would to some extent interfere with the work of publication.

A Member.—I think that the most valuable discussions coming before the Society are the impromptu discussions which take place after the paper is read. If a paper is to be discussed after two or three months, it will lose a great deal of its interest.

The amendment proposed by Mr. Le Van was lost.

Mr. Le Van.—I also asked to change the time of meeting. In the first place every meeting we have had in November, except this one, has been held in rainy weather. It is not cold enough to have a fire here and it is too cold to sit without an overcoat. I do not think the health of the members should be sacrificed in order to have a meeting just on the first or second of November for some reason I cannot account for.

The Secretary.—Such a recommendation as Mr. Le Van mentions was brought forward. But the fixing of the time of the annual meeting is given by the rules entirely to the Council. The matter does not come before the Society at all, and the Council has so far declined to make any change.

The President.—The rule in regard to the matter reads: "The annual meeting of the Society shall be held in the City of New

York on the first Thursday in November, at which a report of the proceedings of the Society and an abstract of the accounts shall be furnished by the Council; the Council may change the time of the annual meeting, and shall in that case give six months' notice to members and associates."

The proper form of amendment here would be one which should take from the Council this authority to change the time of the annual meeting, or should simply take the form of a recommendation to the Council that it be changed. In the first case it would have to go through this form, and should have been proposed in this form. In the second case, as a mere recommendation, it can come in now or at any time.

Mr. Le Van.—I would ask then that it be made a recommendation to the Council to have it changed.

The President.—Cannot Mr. Le Van put that resolution in form?

Mr. Le Van.—Not in any better form than I put it last year.

The Secretary.—There is no such resolution on the minutes, and none came formally before the Society to my knowledge.

Mr. Weightman.—Is there any necessity for such a resolution? I think the Council will take note of it at the mere request of one member.

The President.—In the absence of any resolution of course debate is not in order. Is there any other business of this character offered, or any general business at all? Is any report to be presented by the Committee on Tests of Iron and Steel? That committee is still in existence, and I understand that a meeting of it is set for today.

Mr. Woodbury.—Dr. Egleston notified me yesterday of a meeting of the committee this afternoon, and as he does not seem to be here this morning I take the responsibility of assuming that he will present something on behalf of the committee later during this meeting.

The President.—The next matter in the order of business will be the discussion of earlier papers.

Mr. Wiley.—I simply want to bring before the meeting the fact that we ought to nominate our officers in a different way from what we do now. I do not know just how this matter should be brought up, but I am sure of the fact that the present method ought to be changed.

The President.—It should be carefully considered, and a resolution written out and presented.

Mr. Weightman.—I was requested by the Treasurer to suggest some amendments, and I would move that a special committee be appointed to revise our By-Laws, and to report at our next annual meeting, or, if possible, to report at our next regular meeting, so that such suggestions could be adopted at the annual meeting. I would make the motion that a special committee on by-laws be appointed.

The President.—Would it suit the gentleman as well to put his motion in this form, that a committee be appointed by the new Council? It would be somewhat ungracious for the outgoing Council to appoint committees for the new Council.

Mr. Weightman.—I would put it in that form, or for the Chairman to appoint such a committee.

Mr. Durfee.—I second the motion, and for this reason: I am profoundly of the opinion that we are using up at these annual and other meetings altogether too much time in discussing amendments which are of comparatively little value when viewed in their relation to the real work of the Society, and if there is any means by which we can have some laws that resemble those of the Medes and Persians, that may not be altered, I hope that a resolution leading to such a result will be passed.

Mr. Bayles.—I would like to ask whether the appointment of this committee cuts off the right of the members to amend the rules.

The President.—The amendments just passed upon of course are gone by. Future amendments will be referred to such committee, I should say, if it were formed.

Mr. Woodbury.—The epitaph which should be put on the gravestone of many a disorganized society would be, "Strangled by its own by-laws." While there are many items in our constitution and by-laws which might be more convenient to individual members here and there, yet, as a whole, I deprecate the idea of devoting so much time to alterations which are little more than verbal in their character. The by-laws were very carefully prepared in the first place by persons conversant with the working of similar societies, and who had had long experience in affairs; and while it may be necessary to make changes now and then for the most harmonious and efficient operation of this Society, it seems to me that it would be a retrogression and not a step forward to endeavor to reorganize or to give a committee power which would look to that result in the way of altering our constitution and by-laws. We

come here for professional purposes, and not to quibble over matters of law.

Mr. Weightman.—It was just for that purpose that I made this motion, so that such discussions should take place in the special committee. So far as our by-laws being to a certain extent a matter of death to us, there is one point brought up here, and that is that in our money matters there is constant complaint now that we are running behind. The Treasurer has complained of one point in reference to our by-laws, and that is that nobody is responsible for the money spent. Article XXVII. says that no bill shall be paid for the Society until it has been certified to by the person authorized to contract it, and audited by the Committee on Finance. Now he wishes to know what power there is in the Committee on Finance to audit a bill after it has been contracted by the person spending the money. He being the person authorized to contract the bill, the Finance Committee must necessarily pay it. The auditing of it, the Treasurer claims, is a farce, and he can see no method of governing expenditure so as to keep it in due bounds and within our receipts. Those are points which were taken from the Treasurer at his request. It was at his request that I mentioned these matters. I thought it would cover it better by referring the whole matter to the Committee on By-Laws, when the discussion could take place outside our meetings.

Mr. Rose.—The object of the first mover (Mr. Wiley) was to give the members of the Society some voice in the election of its officers. As we are at present constituted, we are presented with just enough names to fill just so many offices, and therefore the members of the Society have no voice whatever, except so far as they are represented by the Council, in the choice of officers.

The resolution proposed by Mr. Weightman was agreed to.

The President.—If there is nothing further to be offered in regard to the papers presented at the last meeting, we will proceed to the reading of the papers offered for this meeting. We have a paper by Mr. Seaman on "The Rail-Cambering Arrangement of the Lackawanna Coal and Iron Company."

Mr. Seaman read his paper, and discussion followed.

After the discussion of Mr. Seaman's paper, Mr. Hayward read a paper entitled "An Adjustable Cut off for Steam Engines," and discussion followed.

The tellers having opened and counted the ballots, made a

report, announcing the election of the following gentlemen as members of the Society in their respective grades:

HONORARY MEMBERS.

DANIEL K. CLARK, M. I. C. E., London, England.
RUDOLPH CLAUSIUS, Bonn, Prussia.
PETER COOPER, D. C. L., New York City.
O. HALLAUER, Sec. Ing. Civils de France, Munster, Alsace.
G A. HIRN, Correspondent de l'Institut de France, Associé des Académies de Belgique, de Suède, &c., &c., Colmar, Alsace.
FRANCIS REULEAUX, Berlin, Prussia.
SIR EDWIN J. REED, K. C. B., M. P., London, England.
HENRI SCHNEIDER, Le Creusot, France.
C. WILLIAM SIEMENS, D. C. L., F. R. S., &c., London, England.
HENRI TRESCA, Membre de l'Institut, President Honoraire de la Société des Ingenieurs Civils, Paris, France.

PROMOTIONS.

WILLIAM K. SEAMAN, Associate A. S. M. E., Scranton, Pa.
CHARLES C. WORTHINGTON, Associate A. S. M. E., New York City.

MEMBERS.

WILLIAM J. BALDWIN, Superintending Engineer Nason M'f'g Co., 71 Beekman Street, New York City.
THEODORE BERGNER, 424 Walnut Street, Philadelphia, Pa.
M. C. BULLOCK, 86 Market Street, Chicago, Ill.
THEODORE COOPER, 35 Broadway, New York City.
S. ASHTON HAND, Tonghkenamon, Chester Co., Pa.
CHARLES KIRCHHOFF, JR., 27 Park Place, New York City.
GAETANO LANZA, Mass. Institute of Technology, Boston, Mass.
JOHN W. MOORE, Chief Engineer, U. S. N., Champlain, Clinton Co., N. Y.
EDWARD S. RENWICK, 19 Park Place, New York City.
COLEMAN SELLERS, JR., 332 N. 33d Street, Philadelphia, Pa.
HENRY R. TOWNE, Stamford, Conn.
DAVID TOWNSEND, Bush Hill Iron Works, Philadelphia, Pa.
PROF. JOHN BURKITT WEBB, Ithaca, N. Y.
B. H. BARTOL, 1,900 Spruce Street, Philadelphia, Pa.
HENRY LEON BINSSE, 40 W. 19th Street, New York City.
H. M. BYLLESBY, 65 Fifth Avenue, New York City.
JOHN W. CARRINGTON, 579 Classon Avenue, Brooklyn, N. Y.
CHARLES L. CLARKE, 65 Fifth Avenue, New York City.
VINCENT G. HAZARD, The Pusey & Jones Co., Wilmington, Del.
WILLIAM F. MATTES, Scranton, Pa.
THOMAS R. MORGAN, Alliance, Ohio.
HENRY G. MORRIS, Philadelphia, Pa.
A. J. PITKIN, Schenectady Locomotive Works, Schenectady, N. Y.
STEPHEN NICHOLSON, Providence, R. I.
WILLIAM H. PATTON, Virginia City, Nev.
IRVING M. SCOTT, San Francisco, Cal.
EDWARD WESTON, Newark, N. J.

JOHN R. ABBE, Manchester, N. H.
MOSES G. FARMER, Newport, R. I.
CHARLES C. ABBE, South Windham, Conn.
GEORGE W. BIGELOW, New Haven, Conn.
WILMER G. CARTWRIGHT, Stevens Institute, Hoboken, N. J.
J. H. MCEWEN, Supt. McEwen Bros. Mach. and Eng. Works, Wellsville, Pa.
F. A. HALSEY, 249 Broadway, New York.
WILLIAM LEONARD NICOLL, Navy Department, Washington, D. C.
JOHN WALKER, Walker Manufacturing Co., Cleveland, Ohio.
WM. C. WILLIAMSON, Philadelphia, Pa.

ASSOCIATE.

A. ALLER, 109 Liberty Street, New York.

JUNIOR.

SAMUEL HIGGINS, Susquehanna, Pa.

The tellers also reported the election of the following officers for the terms specified in the constitution, as the result of the votes of the Society.

PRESIDENT,
E. D. LEAVITT, JR.

VICE-PRESIDENTS,
JOHN FRITZ,
HENRY MORTON,
WILLIAM METCALF.

MANAGERS,
ROBERT W. HUNT,
CHARLES T. PORTER,
C. J. H. WOODBURY.

TREASURER,
CHARLES W. COPELAND.

After presentation of the tellers' report, Mr. F. B. Allen read a paper on "The Protective Value of Boiler Inspection," and discussion followed.

After the discussion, the meeting adjourned till 2.30 P.M.

AFTERNOON SESSION.

The meeting was called to order at 2.30 P.M.

The President read his annual address.

The President.—There is now an opportunity for any business if any is to be presented this afternoon. If not we will proceed to the reading of papers. Is Professor Robinson's paper ready?

Professor Robinson.—I have brought in two small items at this meeting for the consideration of the Society, and I hope not to take much of the time of the Society with them. One is in regard to the back pressure on valves. The other is a supplement to the paper I read at the Philadelphia meeting on "Pumping Engines." The matter I have to present on the subject of valves was experimentally obtained by a student in the mechanical laboratory of the Ohio State University about a year and a half ago. The question is often raised, I presume, by members of the Society in practice what pressure to allow for a slide valve in determining the resistance of that slide valve. We are at first, perhaps, inclined to take the whole area of the slide valve, multiply that by the pressure in the steam-chest, and call that the pressure of the valve in its seat. I directed these experiments for the purpose of throwing some light on the question.

Professor Robinson then proceeded to explain his drawings.

At the conclusion of this paper, arose

The President.—While we are waiting for the next paper, I have an explanation which I wish to make at the request of Colonel Laidley. Colonel Laidley is the officer of the army to whom we are indebted, I presume, for the bringing up of the form of testing machine finally adopted by the United States Board and built and put down at Watertown. In debate, I think at the last meeting, it was stated that the contract made for that board had been annulled before the board itself had taken action. He says that this was an error; that it became necessary that the board should either have the machine that had been contracted for or lose the money appropriated for it, or annul the contract. The board chose the latter alternative. "Had it not done so, the contract would not have been annulled," he continues, "and I should have had at this moment the machine." He goes on to express his regret at that action. He desired a correction of the statement to be made.

A paper by Mr. Hill on the "Difficulties of Road Locomotion, their Cause and Cure," was read by the Secretary.

Mr. Oberlin Smith read a paper on the "Systematic Preservation of Drawings."

The meeting then adjourned till the following day at 7.30 P.M.

In the evening was held the subscription dinner, attended by a large delegation of the membership. It was held in a room adjoining the headquarters, and several ladies were present. It was a very pleasant reunion.

Friday, November 3d, was spent very enjoyably by the members of the Society in an excursion upon New York Bay, stopping at various points of interest. Leaving the foot of Cortlandt Street pier in a propeller tendered to the Society by the courtesy of the Pennsylvania Railroad, the Hudson River tunnel was first visited on the Jersey City side. Members inspected the compressing plant and could descend to the air-lock in the finished work.

Leaving the tunnel, the excursionists steamed around the Battery, and after luncheon, served in the cabin of the boat, were landed at the Brooklyn tower of the East River bridge. Under the direction of one of the engineers, the society visited the massive anchorage and engine chambers in the approach, and then passed to the roadway to cross the bridge. The somewhat perilous passage was made on the plank foot-way, and the propeller was found at the New York tower. After a visit to the Morgan Iron Works at East 9th Street, the members returned to Pier 19, and were escorted to the office of the New York Steam Company, and listened to a short description of its methods by Mr. Chas. E. Emery. Thence they visited the boiler house of the company in Greenwich Street, and saw the successive tiers of boilers, the arrangements for coal, for draft and for return water. After separating at this point, the members re-assembled at the Turf Club Theater in the evening.

The meeting was called to order at 7.30 P.M.

Prof. Gaetano Lanza read a paper entitled "An Account of Certain Tests of the Strength and Stiffness of Large Spruce Beams," and discussion followed. His paper was illustrated by photographs thrown on a screen by a projection lantern.

After the discussion, the report of the Committee on Gauges was called for and read by Mr. Bancroft, as follows :

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Your Committee on Standards and Gauges have to report that they have examined the Rogers-Bond Comparator in use by the Pratt & Whitney Company at Hartford, Conn., together with gauges for end measure produced by the use of this machine.

This apparatus is used, first to compare line measures of length with attested copies of the standard bars of England and the United States; second, to subdivide these line measures into their aliquot parts and to investigate and determine the errors, if any, of these subdivisions; and, third, to reduce these line measures to end measures for practical use in the shops.

A paper read by Professor W. A. Rogers before the American Academy of Arts and Sciences, April 14, 1880, on "The Present State of the Question of Standards of Lengths," and a paper read by Mr. George M. Bond before this Society at its regular meeting in Hartford, 1881, will give all the needed information on the subject of standards of line measures.

The comparator is provided with two microscopes, their magnifying power being about 150 diameters, each having a micrometer eye piece the divisions of which represent about one sixty-thousandth of an inch, and in reading, these divisions are usually subdivided by the eye into tenths, in every case at least three readings being taken, and the mean of the three is used in calculating the result.

The microscopes are mounted upon a carriage which slides freely upon two cylindrical guides, which are heavy tubes of hard tool steel, carefully ground true and cylindrical. These are supported at their ends in bearings formed in the heavy cast-iron base of the machine. Counter-weight levers are applied under these tubes at about one-quarter the total length from each end, to overcome the flexure arising from their own weight and that of the carriage and stops. These stops are arranged so as to be clamped firmly to the guides at any desired distance apart; they serve to limit the motion of the microscope plate or carriage when brought in contact with either stop. The carriage is moved up against the stops by a rack and pinion which is provided for the purpose, the rack being secured to the bed of the comparator between and independent of the guide bars. The abutting surfaces of the carriage and stops are hardened steel, those on the carriage being spherical, while those on the stops are flat, and each stop is provided with an electro-magnet that serves to hold the carriage firmly against the stop so as to prevent its settling back during an observation.

On one side of the comparator is a table provided with rapid vertical and lateral adjustments and with a traverse parallel with the motion of the microscope plate of about 45 inches; on top of this table is an adjustable plate on which the standard bars are laid to be compared. This plate is provided with fine adjustments for parallelism, focus and end position, and several line-measure standards may thus be compared at once under the microscopes without handling the bars. This is an important feature, as it will be evident that errors due to variations of temperature resulting from handling or from any other cause, must be carefully guarded against. On

the opposite side of the comparator is a fixed table or projecting ledge forming part of the base on which this adjustable plate may be placed, so that standard bars may be investigated on either side of the machine. For regular work this place is occupied by the caliper for reducing from line to end measure. The microscopes are mounted upon the carriage in such a manner that they may be used both on one side or one on each side of the carriage, at variable distances according to the character of the work to be examined.

The comparator is firmly supported on solid brick piers capped with stone, and the movable table, having a traverse of about 45 inches, referred to above, is on an entirely separate foundation, to avoid all disturbance of the microscopes that might arise from moving the table.

Subdivisions of a standard bar may be compared by placing the microscopes say twelve inches apart, if the subdivisions under investigation are feet; the variation being measured or read by means of the micrometer eye-piece. The standard is then moved under the fixed microscopes so as to compare each separate twelve inches successively, their relation being thus determined.

Another method is to fix the stops so that the microscope carriage will have a movement of as near the length of the subdivisions to be examined as may be convenient; in this case only one microscope is used, the carriage moving a fixed distance between the two stops, the subdivisions of the standard being thus compared with a constant quantity, and their relation consequently determined.

Line-measure standards may be compared on this machine:

(*a.*) By referring the standards to a fixed distance between two stops.

(*b.*) By bringing the defining lines under two fixed microscopes placed the same distance apart as the length of the standards to be compared.

(*c.*) By placing two standards to be compared side by side, and placing one microscope over each bar, the carriage being then moved the length of the bars, and the relative length of the standards readily determined.

(*d.*) By placing one standard on one side of the line of motion of the microscope carriage, and one on the opposite side, using one microscope for each bar; by reversing the position of the bars, the mean difference may be found.

(*e.*) By comparing standards by the use of two microscopes placed horizontally, and at a fixed distance apart, so that stand-

ards can be compared in the same position, and under the same conditions that comparisons are made at the United States Coast Survey Department at Washington.

The microscope carriage should move in an absolutely straight line, and the cylindrical guides give perhaps the closest approximation to this condition. Errors, however, will exist; and the correction for possible horizontal curvature of the guide bars is found by comparing a standard with a fixed distance between the stops, first on the left-hand side of the microscope carriage, and afterward on the right-hand side, under the same condition in both cases of temperature, and points of support of the standard and focus; the face of the bar must in both cases be maintained in the same horizontal plane, to avoid errors due to vertical flexure of the guides. The difference of the two comparisons with the fixed or constant distance, furnishing data for calculating the radius of curvature and the position of the center, that is, on which side it is located, and hence determining the sign of the proper correction, whether it be plus or minus, should the amount be appreciable.

The vertical curvature or flexure may be determined in the same way, using the standard bar placed at varying heights, and comparing it with the constant distance moved by the microscope carriage, the microscope and bar being kept always in the same vertical plane to eliminate errors of horizontal curvature.

In transferring from line to end measure, as the two microscopes do not move in the same vertical plane, correction for horizontal curvature, if of appreciable amount, must be applied with the proper sign as remarked above, as in such case one microscope evidently would move a distance differing from that of the other by the difference of the lengths of the subtended chords.

Errors due to vertical curvature or deflection of the guide bars, may be practically eliminated by taking care to keep the surfaces on which the lines to be observed by the microscope are ruled in precisely the same horizontal plane.

The caliper attachment to the comparator provides means for reducing line measure to the practical form of end measure, and consists of a fixed stop and a movable plunger, cylindrical in form, sliding in well-fitted bearings and having a traverse of about six inches. The abutting faces of the plunger and fixed stop are of hardened steel three-eighths of an inch in diameter, and are ground to true plane surfaces which are perpendicular to the line of motion of the plunger.

The plunger is pressed against the fixed stop, and also against anything held between the surfaces of the plunger and fixed stop, by a rod which compresses a spiral spring within the plunger. This rod is clamped to place so as to hold the pressure of the spring constant while the observation is being made, the amount of compression of the spring being made approximately equal in each case. This simple contrivance dispenses with the need of the gravity piece used by Whitworth. No great care need be taken as to the amount of compression of the spring, as no perceptible difference is shown under the microscope when the spring is compressed an amount varying from one-quarter of an inch to two and one-half inches. The line upon the plate on the plunger being about 1-30,000th of an inch in width, and the line in the micrometer eye-piece being in exact coincidence with the ruled line upon the plate, no change of relative position was perceptible during a continued observation through the microscope magnifying about 150 diameters, while the spring was subjected to varying compression within the above limits. The error due to flexure of the end measures is not appreciable in pieces up to six inches in length, but standard bars of twelve inches and longer require supports, and great care must then be taken to have the bar to be measured parallel to the line of motion of the plunger and microscope carriage.

This caliper is used with two microscopes, one of which is over a finely ruled standard bar, and the other over a finely-ruled plate which is attached to the plunger, care being taken to have this plate over its entire line of motion in the same horizontal plane as the surface of the standard ruled bar. The faces of the caliper are brought in contact by the rod and spiral spring, and the microscope adjusted until it bisects the line on the plate attached to the plunger. The other microscope is set so as to bisect the initial line on the standard ruled bar, both microscopes being firmly attached to the carriage; the plunger is now drawn back, the piece to be tested put between the faces of the caliper, and the plunger forced up until the spiral spring is compressed about the same amount as before. The carriage is now moved until the line on the plate is again bisected by its microscope, and the microscope over the standard bar by the aid of the micrometer, determines the exact length of the piece in terms of the subdivision on the ruled standard. This operation can be performed very rapidly, and with uniform results. One accustomed to the use of the micrometer will readily measure within one divis-

ion. A test to determine the accuracy of setting to a single line on the ruled bar made by six members of this committee, most of whom were quite inexperienced in the use of the microscope, showed between the highest and lowest of eighteen readings a difference of 5.5 divisions, a quantity less than 1-10,000th of an inch, while the average of the eighteen readings differed from the average readings of Mr. Bond by four-tenths of one division, or about 1-150,000th of an inch.

The end-measure pieces which your committee were shown at the works of the Pratt & Whitney Company, were stated to be correct within 1-50,000th of an inch; and perhaps the severest practical test was made by laying a number of these pieces in a groove planed in a massive block of cast iron, one piece being clamped down to form an end stop, and when the pieces laid down reached the length of twelve inches, another piece was clamped down. A quarter-inch piece was used as a try piece, and was held by a piece of wood inserted in a small hole passing through the piece; the end stops were adjusted until this try piece would just move easily—almost by its own weight. These pieces were then removed, and others, which had been laid on this cast-iron block so that they might all have the same temperature, were substituted, care being taken not to disturb the end stops; some twelve different sets were tried in this way, the same quarter-inch piece being used as a gauge, and these twelve sets were practically uniform in length, with one exception. In this case the quarter-inch piece was quite loose, and accordingly the end-measure pieces composing this set were all carefully measured on the comparator, as well as a set that had stood the test. The difference in length between the two sets, one composed of nine pieces, and the other of seven, being less than 1-10,000th of an inch, and one piece of the set composed of seven pieces was found to be 1-30,000th of an inch short, being exactly one-half the total error of the entire seven, as compared with the standard bar, and this was found to be one that had been condemned on account of a defect in the end surface.

Dividing the total difference by the number of pieces in the set, the difference noted above, of 1-10,000th of an inch between the total errors of the two sets referred to, shows an average difference for each piece of the first set, as compared to the length of the second set, of about 1-75,000th of an inch, and about 1-105,000th of an inch as compared with the subdivisions upon the standard bar, to which they were referred.

The end-measure pieces being all referred to lines ruled upon a hardened steel bar, and in a manner which reduces possible error to a minimum, the liability of a deterioration of the standard is eliminated; error would certainly result were they all compared with a standard end-measure test piece, the use of which, however slight, would be attended with more or less wear, and the original size thus lost; this *ruled bar* being preserved, the *originals* may be duplicated at any time. As the standard ruled bar is not handled or touched in any way during the process of measuring, the only risk of change would seem to be that due to internal strains in the standard itself. This point will require close investigation and comparison with other standards, to determine the stability of the hardened bar. This standard has been submitted to a process of annealing, at a temperature above any ordinary atmospheric heat due to climate, and this annealing is believed to eliminate the risks of after changes. A recent examination of this standard, which was so treated two years ago, shows no appreciable change.

Two adjoining sides of the end-measure pieces are first ground by special machinery to plane surfaces, which are perpendicular to each other, and the end surfaces are afterwards ground to true planes parallel with each other and at right angles with these side planes, by the use of a fixture which consists of a block having a slot through its center, the sides of which are exactly perpendicular to the base of the block. The block slides over a plane surface in the center of which is a copper plug charged with emery or diamond dust. The end-measure piece is secured in this slot and passed over the copper lap until the end is reduced to a polished plane surface; the piece is then reversed and the other end ground in like manner, careful measurements being made from time to time as the piece is gradually reduced in length, great care being taken to have the temperature correspond with that of the ruled bar. The test of these end measures in the groove in the block of cast iron above referred to shows the accuracy of this method of manufacture, as any want of parallelism in any of the ends would seriously affect the total length of the set.

Between and below the jaws of the caliper is a small table, which can be adjusted vertically for the purpose of calipering cylinders; the table is adjusted so as to bring the center of the cylinder to be measured to about the same height as that of the plunger, the axis of the cylinder being horizontal; the plunger is then pushed against the cylinder by means of the rod and spiral spring above

described. The pressure of this spring is sufficient to move the cylinder on the table until its sides are tangent to the plane surfaces on the plunger and fixed stop; by moving the cylinder back and forth it can be tested for parallelism, and by turning it, the plunger being in each case released and brought into contact again, it can be tested for rotundity, the whole operation requiring but a few moments.

The personal error in reading by microscope—that is, the variations different individuals would make in reading the intersection of the lines by the micrometer—is eliminated by the process of measuring, the microscope being in each case set to the zero on the ruled bar when the caliper faces are in contact, and also to the proper line when the object to be measured is between the jaws of the caliper; and hence any individual difference there may be in setting will be the same for the readings at each point, *i. e.*, at zero and at the position due to the length of the measured piece; and the difference between these two readings gives the length of the piece in terms of the standard bar. As the standard bar used by the Pratt & Whitney Co. for all measurements of four inches and under is of the same material as the end-measure pieces and plug gauges, no correction for temperature is required, the only precaution being that the piece to be measured shall be at the same temperature as the standard bar, which is readily accomplished by keeping them together for a few hours before measuring.

CONCLUSION.

The completion of the Rogers-Bond comparator marks a long stride in advance over any method hitherto in use for comparison and subdivision of line-measure standards, combining, as it does, all the approved methods of former observers with others original with the designers. Comparisons can thus be checked thoroughly by different systems, so that the final result of the series may be relied on as being much nearer absolute accuracy than any hitherto produced.

The calipering attachment to the comparator deserves special commendation, being simple in the extreme, and solving completely the problem of end measurements within the limit of accuracy attainable in line reading, by means of the microscope with the micrometer eye-piece. The standard to which the end measurements are referred is not touched, and each measurement is referred back to the same zero, so that error from end wear does not

enter into the problem. This attachment is in advance of all hitherto known methods of comparing end measures, either with other end measures or with line standards, both as to rapidity of manipulation and accuracy of its readings. The strong point in its construction being that it refers all end measures to a carefully divided and investigated standard bar, which is not touched during its use, and cannot be in the slightest degree injured by this service, thus giving convincing assurance that the measures and gauges produced by its use will be accurate and interchangeable.

In the opinion of this committee, the degree of accuracy already attained is such that no future improvements can occasion changes sufficiently great to affect the practical usefulness of the magnitudes here determined, or the interchangeability of structures based upon them with those involving further refinements.

Professor W. A. Rogers and Mr. George M. Bond are unquestionably entitled to great credit for the admirable manner in which they have solved the problem of exact and uniform measurement, while the enterprise of the Pratt & Whitney Co., in bringing the whole matter into practical shape, is deserving of the thanks of the engineering community.

J. Sellers Bancroft,
Secretary of the Committee.

Henry Morton, *President.*
S. W. Robinson.
Oberlin Smith.
E. H. Parks.
Ambrose Swasey.
Chas. T. Porter.
Alfred Betts.
George R. Stetson.

The President.—Is there any discussion on this report?

Mr. Miller.—I move that the report be accepted with thanks, and ordered to be printed.

Agreed to.

The report of the Committee on Tests of Iron, Steel, and other Metals, was read by Professor Egleston, as follows:

"The Committee on Tests of the American Society of Mechanical Engineers beg respectfully to report that they printed and sent

out 3,750 copies of the memorial which was adopted at the Philadelphia meeting, to the colleges and technical schools of the United States, to the iron and steel manufacturers, to the members of the American Institute of Mining Engineers, the American Society of Civil Engineers, and the American Society of Mechanical Engineers, and to the mill insurance companies of the New England States.

"Up to June 1st, 1,500 signatures, with the profession and addresses of the signers attached, had been received to the memorial. Copies of all of them were sent to the Hon. J. M. Campbell, Chairman of the Committee on Manufactures of the House of Representatives. The originals it was thought best to retain for future use, and they are now in the possession of your committee. It is believed that many signatures to the memorial were sent independently, and of these no copies have been sent to the committee. At the request of the Committee on Manufactures, every member of both Houses of Congress was furnished with a copy of the discussion on tests at the Philadelphia meeting.

"Your Committee also issued two circulars, which were sent with the memorials. One was sent to colleges and technical schools, asking their Faculties to send to the Hon. J. M. Campbell, at Washington, resolutions indorsing this memorial. The other requested those to whom it was sent personally to urge the support of the bill upon the Representatives from their district, and Senators from their State. A copy of each of these circulars is appended to this report.

"The committee had several interviews with Hon. J. M. Campbell, and with a number of other members of the House and Senate, and received from them the assurance that if the bill H. R. 4,726 did not pass Congress at the session of last spring, they would do their utmost to have it pass during the coming session.

"Your committee believes that the vigorous efforts made by the Society had a great deal to do with the passage of the appropriation of $10,000 for the use of the testing machine at Watertown.

"In the judgment of this committee, it seems worth while that the efforts of the Society in this direction should be continued during the coming year."

Appended are copies of the circulars issued by the committee:

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

COMMITTEE ON TESTS.

NEW YORK, *May 22d*, 1882.

GENTLEMEN:

A bill proposed by the American Society of Civil Engineers, in conjunction with members of the American Society of Mechanical Engineers and of the American Institute of Mining Engineers, for the appointment of a commission to test metals and materials used in construction, and numbered H. R., 4,726, has been introduced into the House of Representatives, and unanimously reported to the House for passage by the Committee on Manufactures, of which Hon. J. M. Campbell, of Pennsylvania, is Chairman.

We are informed that, in order to have this bill become a law, interest in it must be shown, and it must be made evident that those interested in education, men of science, engineers, and others feel the need of such a commission. We therefore beg to ask you that the Faculty of your Institution will pass resolutions in favor of such a measure and forward the same to the Chairman of this Committee, to be sent to Washington with the least possible delay. Also, that you will use what influence you are able to command to induce Members of Congress to favor the creation of the commission.

In view of the magnificent industrial development of this country in the past, as well as its present prosperity, so much of which is due to the scientific knowledge and practical skill of our constructive engineers, the working capacity of whom can be so greatly augmented by a knowledge of facts, obtainable in the manner above mentioned, at a much less cost than by imperfect individual research, the committee request your assistance in this matter.

T. EGLESTON, *Chairman*,
School of Mines, E. 49th Street, N. Y.
E. D. LEAVITT, JR., *Cambridgeport, Mass.*
W. METCALF,
Miller, Metcalf & Parkin, Pittsburg, Pa.
OBERLIN SMITH, *Bridgeton, New Jersey.*
C. J. H. WOODBURY,
13 *Devonshire Street, Boston, Mass.*

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

COMMITTEE ON TESTS.

NEW YORK, *May* 22, 1882.

DEAR SIR:

The bill for Testing Metals and Constructive Materials has been unanimously passed by the Committee on Manufactures, at Washington, and will soon be put on its passage in the House of Representatives. A vigorous opposition to it has been developed. The Committee of this Society is urged, by the Hon. J. M. Campbell, to secure influence in favor of the bill from as many quarters as possible. At his suggestion, you are earnestly urged to write *yourself*, *at once*, and to get others interested in the bill to write to both the Representatives from your District, and the Senators from your State, urging the passage of the bill as a measure likely to promote the welfare and interest of the United States.

A special edition of the debate at the late meeting of the Society in Philadelphia, is now being prepared for the use of Members of Congress.

Yours, truly,

T. EGLESTON, *Chairman*,
School of Mines, E. 49th Street, N. Y.
E. D. LEAVITT, JR., *Cambridgeport, Mass.*
W. METCALF,
Miller, Metcalf & Parkin, Pittsburg, Pa.
OBERLIN SMITH, *Bridgeton, New Jersey.*
C. J. H. WOODBURY,
13 *Devonshire Street, Boston, Mass.*

Prof. Hutton.—I move that the committee be thanked for its services, that the committee be continued, and that the report be accepted and printed.

Agreed to.

Mr. Woodbury.—I move that the Secretary of the Society be instructed to transmit to the Pratt & Whitney Company of Hartford, Connecticut, an attested copy of the report of the Committee on Standard Measurements.

Agreed to.

Mr. Oberlin Smith.—I beg to offer this resolution:

Resolved, That the hearty acknowledgments of this Society are due to the Pennsylvania Railroad Company, the Hudson River Tunnel Company, the Brooklyn Bridge Company, the New York Steam Company, the Morgan Iron Works and the Brush, Edison, and United States Electric Lighting Companies, for courtesies rendered and attentions shown to its guests and to itself, and that the Secretary be ordered to convey to them the sense of this resolution.

Agreed to.

Mr. Woodbury.—I beg to offer this resolution:

Resolved, That the thanks of the Society are due to the local Committee of Arrangements for the annual meeting, and especially to its Sub-Committees on Excursions and on Printing and Press Notices, for their most effective and satisfactory action in the duties with which they have been respectively charged, and that the Secretary is hereby instructed to communicate to them this resolution.

Agreed to.

The President.—A part of our work of yesterday has been omitted. We had a paper by Mr. Smith on "The Preservation of Drawings," and we were compelled to omit the discussion of the paper owing to the lapse of our time this morning. Has any gentleman any remarks to make upon the paper on "The Preservation of Drawings," which was heard yesterday? Is there any discussion? If not, we will go on to the next paper by Prof. Webb on a "New Form of Indicator."

Prof. Webb then read his paper, and discussion followed.

At the close of the discussion, the President gave the invitation to visit the stations of the electric lighting systems.

The President.—I will say here, before calling for another paper, that the gentlemen are expected to meet the Presidents of the Electric Lighting Companies immediately on adjournment. They will explain their methods at the Hoffman House, and then there will be an opportunity of visiting their stations and seeing the machines in operation. Is there any other business to be presented?

Mr. Holloway.—I do not know that it is necessary to make a motion; but I desire to say, before the meeting closes, that some of us would desire to have the committee on future meetings, or the Council, take into consideration the advisability of having the next meeting in some Western city—possibly Cleveland.

The President.—The Council have taken no action as yet in the matter, and there has been no invitation extended to the Society to meet at any other point. There is a strong disposition among

members of the Society and of the Council with whom I have talked to make the next meeting a Western meeting; the feeling being that we are localizing our Society too much by having so many meetings at the East, and it is probable that a favorable inclination will be formed to meet in Cleveland in the Spring.

Mr. Holloway.—I would say on behalf of the Western members that such a plan would be satisfactory to them.

A paper by Mr. Alfred Colin on "Technical Schools for Artisans" was read by the Secretary, and elicited no discussion.

After a paper by Mr. Norman Wheeler, entitled "Launching Ships Side-On," was read by title, the meeting adjourned, subject to the call of the President and Council.

After adjournment the members repaired to the Hoffman House to inspect the effect of electric light on paintings, and were thence escorted to the station of the U. S. Electric Lighting Co., using the Weston Dynamos, and to the station of the Brush Illuminating Co. It had been planned to visit also the Edison station, but on account of the lateness of the hour the plan was not carried out.

ALEXANDER LYMAN HOLLEY—A MEMORIAL ADDRESS

BY

R. W. RAYMOND, PH. D., NEW YORK CITY.

MR. PRESIDENT, GENTLEMEN OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS, THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, AND THE AMERICAN INSTITUTE OF MINING ENGINEERS; LADIES AND GENTLEMEN:

The memorial session in Washington, at which I was first designated for the duty of this evening, was chiefly devoted to the multiform expression of sorrow. From a score of speakers, who had known Mr. Holley in various stages of his career, came tributes of affection, honorable alike to him and to them. Among them all, none uttered words more heartfelt and impressive than did the venerable Ashbel Welch, who, by reason of official position, as well as years and character, would doubtless have been called to preside over this meeting, had not a more potent message summoned him meanwhile to a higher seat. Nestor mourned over Achilles, slain in the midst of the battle; and now Nestor, too, from the peaceful life of an honored old age, has passed away.

But neither this more recent, nor that earlier, grief is the theme of the present hour. However inadequate to the task the orator of to-night may prove, it was fitting that some one, waiting until the first outburst of emotion had died away, should attempt a calm review of the life and works of Alexander Lyman Holley; that Friendship, bewailing her loss, should give way to History, counting her gain; that the achievements of the departed should be recognized and valued, and his example studied. Was he greatly successful? How did he win success? How much of it was born with him; how much thrust upon him; how much earned by him? And if his own hands wrought out his fame, is there any thing in the method of his preparation and practice that others might imitate with profit?

Mr. Holley was born at Lakeville, in Salisbury, Conn., on the 20th of July, 1832. His father, Alexander H. Holley, subsequently Governor of that State, was a native of the same village. His

mother, whose maiden name was Jane M. Lyman, was one of the Lymans of Goshen. The experts in New England genealogies will not need to be told that, on both sides, he came of a good stock—such as, by a combination of enterprise, intelligence, and high principle, has made New England great. The mother could, indeed, bestow upon her son nothing more than the legacy of inherited character, for she died a few weeks after his birth. But her place was supplied by the second marriage of his father, three years later, to Miss Marcia Coffing, whose affection, bestowed freely upon her stepson through twenty years, was as freely returned by him. Their correspondence, some of which has been preserved, shows that their personal intercourse was intimate, and that this excellent lady, though burdened with the cares of a large and hospitable household, never forgot to be a true mother to this son of her adoption, as well as to the children born of her. No doubt he was much indebted for noble impulses and principles to the influence of this devoted woman.

For two or three years of his early boyhood he attended the district school near his father's house, and was then advanced to the Academy, to which he walked, a little more than a mile and a half, every day, winter and summer. In later life, he was accustomed to allude to this regular exercise as having laid the foundation of the fine constitution which enabled him, for so many years, to work so hard and yet so easily.

From the Academy in Salisbury he went to another, under the care of Mr. Simeon Hart, at Farmington, Conn., and after a year or more, to Williams Academy, them directed by Mr. E. W. B. Canning, at Stockbridge, Mass. From Stockbridge he went to Bridgeport, Conn., to prepare for Yale College, under Rev. Henry Jones. According to the dates and internal evidence of his boyish letters, the above order is not strictly correct. I find him at Stockbridge in 1846 and 1847, at Farmington in 1848, at Bridgeport in 1849, and back at Stockbridge in 1850. For our present purpose, the question is not important, except as it shows an early trait in his character—a restlessness, born of versatility and genius, which under less judicious training might have wasted his life.

Ample and interesting materials tempt me to more detailed description of his boyhood. But I must be content to mention, and briefly illustrate, its leading characteristics. First among these must be named the normal, healthy physical activity and the overflow of mirth and high spirits which made him a leader in boyish

sports and adventures. Where the others climbed with ostentatious courage up to the belfry of the academy, he, at the first trial, mounted above it and stood on the gilded ball, which no foot had pressed before. He hangs over precipices, takes long foot-journeys, and revels in mere consciousness of life and strength. Strikingly handsome as well as athletic, he is naturally a leader among his comrades. In all sorts of home amusements, too, his merry ingenuity makes him invaluable. Many of these, such as charades and rhyming games, were intellectual; others were mere pranks—such as the match between him and a friend, "who could eat the most pancakes," of which the kitchen was the scene, the cook being coaxed into complicity, and the dog, wagging his tail behind the combatants, received from each as many segments as could be surreptitiously bestowed without the knowledge of the other; or the occasion, when, having constructed a rustic bridge over the brook, Holley forced the entire family to march over it in solemn procession, while he sat by, fantastically dressed as a troubadour, and played the guitar.

Let no one despise this light-hearted gayety. It was the early form of that courage which carried him afterward through many struggles and even defeats, with an air of victory that was in itself the promise of victory to come.

To this quality must be added a keen observation and an inborn talent for drawing. These were specially, but not wholly, directed toward machinery, in which he took the liveliest interest. His father having established the well-known knife manufactory at Lakeville, the boy made himself familiar with all the machinery, and during his youth made innumerable proposals of improvement—some of which, being really good, were adopted, while others—no doubt the greater number—were crude and impracticable. When but nine years old, he accompanied his father as far as Niagara, where he was left for a few days with an uncle who was connected with works employing machinery. During the father's absence, Alexander was repeatedly missed by his uncle, who always found him on such occasions in some place where there was a steam-engine, and who long preserved, as a memento of the visit, a little bundle of papers on which the boy of nine had made drawings of the different machines he had thus studied. In a letter written at about the age of fourteen, he describes an excursion with his schoolmates to the old Bristol copper mine, six miles from Farmington, and says:

"The steam-engine attracted considerable of my attention, of course. It was splendidly made and fitted, and went so still that one would hardly know that it was in the room. Power, twenty-horse. Mr. S. Hart [his teacher] told the gentleman that showed us around that he would have me draw a plan of the engine from memory, which I have done, and which Mr. H. is much pleased with. He says he is going to send it to the aforesaid gentleman at Bristol."

His letters overflow with revelations of his passionate interest in machinery, and particularly in locomotives. In one of them, written after returning to school from vacation, he indulges in some of the truly good sentiments with which boys are wont to please parents, but which are in this case redeemed from platitude by this picturesque touch:

"It seems as if I should dive and dig and plow, and if that did not succeed, back out and plow again, in my studies, as faithfully as the locomotive old 'Connecticut' did, this morning in the drifts, with seven long cars, all alone."

In another letter, he speaks of a locomotive which has been wrecked on the Housatonic road; calls it by name, as an acquaintance; says he has walked twice (a number of miles) to the place where it lies at the bottom of a steep embankment; introduces a pen-and-ink sketch of the scene, locomotive and all, to show how difficult will be the return of the engine to the track; and concludes, "I guess the H. R. R. Co. will not make money by this operation."

He frequently declares his determination to master the science of machinery, and I find one sentence, in a letter written at fifteen, which seems to be an unconscious prophecy. He writes:

"I have seen, in a newspaper, an account of a man in England who makes steel that will cut iron or any other hard substance without dulling it. I should like to hire out to that man for a year or so. * * * I wish I could learn the art of making steel."

Twelve years later, there was a man in England by the name of Bessemer, of whom he took, in this art, lessons that were not wasted!

In another letter, written from Stockbridge, he says:

"I have been devoting all my leisure time, for nearly two weeks, to making sectional and perspective views of the internal works, machinery, steam-works, etc., of the most improved locomotive engines, showing how the steam is made, applied, and cut off at half-stroke or not (a recent improvement); how the engine is worked every way, in some seventeen different pictures, with explanations filling some eight or ten pages. Mr. Canning is to have them framed and hung up in the Academy. I have explained them in such a manner that any one can understand them, and I really hope that people will look at them, for there is more ignorance among scientific and educated men on this point than

on any other. People who pretend to 'know the ropes' cannot explain the simplest form of a steam-engine, even with a model. Of mechanics and chemistry, I intend to get the most thorough knowledge, if I have the opportunity (and, in fact, I intend to get it any way), both practically and theoretically. These are the studies I have always liked, and I am bound to investigate and become master of them."

One other characteristic deserves special mention—his talent for debate and literary composition, and his consequent love of them. Let it be said here that his was not an instance of dropsical precocity. His early efforts were not mature, or even suprisingly early. At fourteen he joined, I believe, his first debating society. I have found, in his handwriting, a constitution and by-laws of the Societas Literarum (symbolized by a Greek Sigma), which bear date about this time, and in their simplicity and brevity are worthy of imitation. The constitution runs thus:

"1. It shall be the duty of each member to try to sustain the society.

"2. Each member shall pledge his word of honor to keep all the proceedings a secret.

"3. The business of the society shall be debating and composition reading.

"4. This society shall support a semi-monthly paper, called the ——." [Name omitted.]

And the following are the by-laws:

"1. The officers of the society shall be a secretary and a president.

"2. There shall be as many as eight members in the society.

"3. It shall be unlawful to use vulgar or profane language."

It was not long, however, before, in this congenial sphere, he developed extraordinary activity. I cannot forbear to introduce, at this point, the letter which appeared in the *American Machinist* of March 18th, 1882, from Mr. Canning:

"The universal sorrow in the inventive and mechanical world over the recent decease of A. L. Holley prompts me to jot down a few particulars of his earlier school experiences, which go to prove the truth of the proverb, 'The boy is father of the man.'

"Mr. Holley entered Williams Academy at Stockbridge, Mass., in the fall of 1848,* then under my charge. He is still remembered as a fair, fresh-cheeked, blue-eyed, wide-awake boy of sixteen, who pursued studies preparatory to a college course. His geniality, generosity and overflowing good humor made him popular with his schoolmates, and soon gave him the lead, both in and out of school. He excelled in every branch of study; but his chief interest centered in Natural Philosophy and Mechanics. He was a prominent member of a literary society of the institution called the 'Philologian,' in which he mani-

* Mr. Canning forgets his first sojourn at the school. He was certainly there in 1846 also.

fested talent unusual for his years for debate and free discussion; while his fun-loving propensities found vent in conducting mock trials and in humorous essays and declamations. He established and mainly conducted a periodical entitled *The Gun Cotton*, issued fortnightly on a large sheet in manuscript, which was read by himself from the desk, and afforded great interest and amusement by the variety and spice of its contents. This he edited during his stay at the Academy.

"Though excelling in all the branches of study required of him, his *penchant* for mechanics and invention developed itself markedly when he attacked Natural Philosophy and Physics. Dissatisfied with the meager description in the text-books of the steam-engine, with which he seemed to be better acquainted than the authors of the treatise, he at my request made drawings in detail of a stationary engine and of a locomotive, with an accuracy and skill that would have done credit to a professional engineer or draughtsman. These I used in demonstration, in preference to the imperfect model among the school apparatus. During one of his vacations, he came up from his Salisbury home expressly to show me a miniature engine of his own building. It was complete in all respects, and of skillful workmanship; and, on being fired up, ran with admirable success. Thus he foreshadowed the devotion to the mechanic arts which so eminently characterized his manhood. One number of his *Gun Cotton*, I remember, was devoted to the description of an aërial voyage made by a machine of his own devising, whose practical workings were related with as much interest as the details of the wonders of sight-seeing it enabled its inventor to describe. This, he prophesied, would be substantially the vehicle of locomotion A.D. 1950.

"His temperament prompted him to constant activity. There was not a lazy bone or muscle in his body. In fact, his mind was too powerful for his physique; and, beyond doubt, the continued high-pressure at which he drove his mental energy, during all his busy life, materially shortened his days.

"In his reading he was fond—though by no means exclusively so—of works of imagination. Every new invention that fell under his eye received due notice in his *Gun Cotton*. Imaginative works seemed to be the whetstone on which he sharpened his own inventive genius. It is rare that good sense and sound judgment succeed in subduing the *imagination* to become the servant of the *practical*, to the extent realized in the case of Mr. Holley.

"Your brief but comprehensive article in the *American Machinist* of 18th of February follows the career of Mr. Holley subsequently to his college life. Doffing the student's toga for the workman's blouse, he put to the test the best theories of his book-learning, and showed the world, to its immense benefit, the unusual example of a man possessing the combination of enlarged education, inventive talent, and practical common sense.

"*Stockbridge, Mass.* E. W. B. CANNING."

To this life-like picture no improving touch could be added, unless by the hand of the subject himself. One or two quotations from Holley's letters of this period will be their own sufficient apology.

Writing from Bridgeport, at seventeen, and giving, as was his custom, an account of his doings, he says:

"I have written the following compositions:

"1st. A Dream, personifying Wisdom (a judge), History, Chemistry, Mathe-

matics and Philosophy, who speak of their respective merits. Philosophy wins the prize. 6 pages of foolscap.

"2d. A Fragment (revised from a former) containing a few thoughts like those in Gray's Elegy. 2 pages.

"3d. History of Audax Promptusque. A novel. 26 pages.

"4th. War (revised from a former). 4½ pages.

"5th. Pride (rather disconnected). 2 pages.

"6th. A Picture. 6¼ pages. On this I have spent in all at least twelve hours' hard study, and it is the best composition I ever wrote. I would like to have you read it.

"7th. A Dream and Consequent Wish. The best I ever wrote, except No. 6.

"8th. A composition in blank verse. Unfinished."

In January, 1850, he writes from Stockbridge:

"I write you in great haste, to say, that at the close of the term we're to have an exhibition. I was first chosen to write and speak a valedictory oration. Then I have to write the *Gun Cotton*, and a continuation of a treatise on the manufacture of pocket cutlery (which I have been at several weeks), for the *Experimenter*, another paper—all this for the day of exhibition. Then the forenoon of the day is to be occupied by a lawsuit. The Philologian Society have, for that occasion, resolved themselves into a 'high court of inquiry,' and I am chosen for 'State's Attorney,' to prosecute a man for 'assault and battery.' This will be public. Besides this, I have to write a continuation of my treatise on 'Cutlery' for the *Experimenter* next week, and to write two numbers of another paper I publish, called the *Locomotive*. Then I have to prepare also for a public trial next week in the Philologian, also to learn (probably) a part in a dialogue for exhibition, and all this in addition to Latin and Greek. My request is this, that I may omit my music lessons till next term, as I have my hands full, and shall burn some of my irons, if I don't look out.

"I shall also want a new coat to expatiate in on the great day. Please send as soon as convenient."

The treatise on "Cutlery," above alluded to, was subsequently accepted by Poor's *Railway Journal*, and published in successive numbers of that paper during the summer of 1850. It is a curious compound of learned extracts from such books of general chemistry, etc., as were accessible to the young author, and admirably clear and vivid descriptions of the actual processes of the manufacture with which he was personally familiar. In his ambitious view, the subject of pen and pocket cutlery includes the natural history and chemical and physical relations of iron, steel, brass, copper, zinc, German silver, tortoise shell, etc. No element is mentioned without a conscientious statement of its chemical equivalent, and the manner in which it is produced or found in nature. But these adornments of the essay, probably its principal merits in the author's opinion, are worthless in comparison with the practical details, which no doubt chiefly commended it to the publishers.

This was, I think, the first literary work for which he received pay. In an exultant but apologetic letter written in July, 1850 (after the publication of the treatise had begun), he confesses that he had made a surreptitious journey from Stockbridge to New York:

"I walked before sunrise to West Stockbridge, went to Hudson and down the river on the *Alida*. Called on Mr. Poor, who was sorry he had paid no attention to my dozen letters, and as a compensation gave me the equivalent of about sixty dollars for my essay. That is, he gave me $25 in cash and 27 copies of every chapter of the article, thus making probably 243 *Railroad Journals*. * * * He says I had better enlarge the essay a little, and come down in vacation to New York, when he will introduce me to a house in New York, who are perhaps the largest publishing house in New York. He thinks I can sell the copyright. I saw the steamship *City of Glasgow* sail. City in mourning for General Taylor. Left the city at three o'clock. We had two locomotives and eleven cars full out."

One further trait, and our picture will be as complete as circumstances will permit us to make it. I have already alluded to the restlessness of Holley's mind. He is drawn by many tastes and ambitions in many directions, though through it all his dominating tendency may be perceived. He is impatient of processes and longs for results. Sometimes his distaste for the drudgery of books and the discipline of school rises to despair. Thus he writes from Bridgeport, in 1849, to his father a letter from which I take the following extracts:

"I have had every thing done for me that could be done—every thing that kind parents could possibly do for a son. I have made three trials, and each one has proved unsuccessful—three trials to get an education; and now having spent so much of your money and trouble, I wish to make one trial at work; and I know I can succeed. * * * It is a waste, sir, I think, to send me to school. It is not in my nature to deprive myself of an education if I was able to get it; but I see the folly of it. I have tried as hard as I could to learn out of books, but it is folly in the extreme. *If* I have any talent at all, it is for writing. When I lay myself out and spend many hours on a composition, I can, by copying all the good parts, make out quite a piece; but this is *all* the talent I have got, *any way*. Now I have got hands and can work. * * * There is John [his brother], a natural scholar, who could not bear hard work, and who will make, by his mind alone, a great man; but I can work, and do nothing else to any advantage. * * * I am very anxious, of course, to hear your decision, and will come, if you say so, with a right good-will; but if not, it all looks *dark* ahead, and I do not know what I shall do. * * * P. S.—Please write to-morrow, as I am very anxious to hear."

The key to this exaggerated confession of failure doubtless lay in the fact that at this time he was preparing for the classical course at Yale, and was giving a good deal of trouble to the Rev. Mr.

Jones. Moreover, going home to work meant escaping from the bondage of Latin and Greek to the whirring wheels, the engine, the forges, the tools of that *knife-factory!* On one hand, purgatory; on the other, paradise; what marvel that to his vision the disciplinary pains of the former took on the hopeless hues of utter despair?

I violate, in this one instance, the rule I have elsewhere pursued in the treatment of private correspondence intrusted to me, by quoting from the reply to the foregoing letter:

"I am very sorry to see you yielding to so desponding a tone of spirit. You are not quite the dunce you would attempt to make me believe you are, nor have all your experiments to secure an education failed, as you would intimate. You certainly know more than you did, when you commenced your career abroad, about books and about men and things. I have certainly had two or three reports to that effect. Why then do you despond? I have not complained of your scholarship in writing to you. * * * This complaint has been on your part and not on mine. * * * No, my son, you must not despond. If dark days now appear, brighter ones will follow. * * * Have you not often heard me say how grateful I always felt to my father, that he did not indulge me in my propensity for change? I think I should have been a ruined man if I had been permitted to hop from this thing to that, and hither and yon, just as fancy for the time might dictate. I wished to leave the store and engage in farming. He said no, and I felt hard about it; but I have often since thanked him for that *no*. Besides, suppose you were to leave school and engage in business systematically (which you never have done yet), and were subject to the drill which you must be, when that time does come, would not that after awhile be as irksome as anything else? * * * You are in the right way now, my son, and your future happiness, usefulness, and respectability depend upon a continuance in this. Of this, I assure you, as a father most earnestly desiring your happiness as well as usefulness.

"If you are not ready to enter college at the next commencement, then go on till you are ready. There are more years to follow. Only make good use of your time, and we shall all be satisfied. * * * You say you think you have *one* talent at any rate. I think you have more; but cultivate *that* at all events, and do all you can towards cultivating others. The cultivation of this very talent may yet be essential to your success in life.

"But always remember one thing, my son. It is an injunction of the Most High. Man is to earn his bread by the sweat of his brow. From this there is no escape. Therefore we must keep on in our employments, whatever they may be; and the more cheerfully we do so, the happier we shall be. Brighter days are before you, and you will so see it ere long. Be contented, then, and make us happy and yourself happy, and all your friends happy, by a cheerful perseverance in the duties before you, which are not *always* study, but in after years the *fruit* of study, and all will be well."

An excellent letter; and there were many more of the same sort. But wiser than wise words was the step that followed; for the father, while holding a firm hand upon these wayward moods, was not blind to the needs and impulses of the genius beneath them; and

in 1850, Brown University having just established a scientific course, Alexander was entered at Providence instead of New Haven. From this time on, nothing was heard of discontent in his study. In October, 1850, he writes:

"I have succeeded, by working nights and in odd hours, in making a painting of the fastest locomotive in the city, which I showed to the Professor of Mathematics. He was pleased with it, and asked me to go with him and look at the locomotive, and to explain to him a new invention in locomotive engineering, called 'link-motion,' which I did satisfactorily. I considered this quite an honor, as he had explained the steam-engine to classes for a dozen years or more. He then took me into several factories where I could not have gone without him."

Besides the picture above referred to, he finished a working-model of a steam-engine, which the professors assured him was the best they had ever seen. And what was more important, he invented a new cut-off, concerning which the following extracts are interesting:

"Brown University, November, 1851.—* * * I have noticed Professor Page's engine, of which father speaks. As he says, it will eventually do away with steam, but *not yet*. I understand his magnetic engine perfectly. It is just as capable of improvement as the steam-engine—and more so. Machinists' work is also quite as necessary for it as for steam-engines. At any rate, I have invented an improvement in steam-engines, and it is bound to be patented, if I sell the coat on my back to pay for it, and go without any. I have showed my plans to a man who was four years with Messrs. Corliss & Nightingale, of this place. These men have invented and are making the most improved cut-off engine of the day, and this gentleman says that my engine (that is to be) embraces all their improvements and none of its disadvantages."

"January 14th, 1852.—After many attempts to get time, I have at last succeeded in putting my new cut-off on paper. Professor Caswell says that it will work as well as Corliss's celebrated cut-off. Professor Norton says it is very ingeniously contrived, and is better than Corliss's. To-day I took it to Mr. Greene (of the firm of Thurston & Greene, the most extensive engineers in the city), and he said it would work as well as any cut off he ever saw. He said I could not get it patented, for this reason. A man, some years ago, got up a cut-off, and in his patent it was provided that he should own all improvements in the cutting-off of steam by the regulator, wherein the valve-motion was obtained by any *connection* with the working part of the engine. My cut-off is *entirely* different in principle and form from his and from all others; yet Corliss himself, whose cut-off is different from his and mine, is to-day involved in a law-suit with the original inventor. * * * I feel satisfied, at all events, that my plan is entirely original, and as good as anybody's. * * * I can have a picture and description of 'Holley's Improved Cut-off' circulated in *Appleton's Engineers' Journal* [he means the *Mechanical Magazine*], free of expense, and shall immediately do so. [This cut-off was illustrated and described in the *Mechanical Magazine* in July, 1852. It is a detached escapement, operated both directly by a cam (at the end of the stroke), and indirectly from the governor, at any point during the stroke.] * * * You advised me when I was home to consult Mr. Adams, C. E., of New York,

about my oscillating engine. I did consult him, and found that my fundamental improvement, on which the rest depended, was patented in England by a celebrated engineer, some years ago. I thought it all out myself, and never heard of it till I had put it on paper myself."

Although such matters as these occupied much of his attention, he was active in the literary society to which he belonged. A letter to his step-mother pours out his wrath at the injustice to which the college societies were subjected by the President and trustees, when, desiring permission to meet in the evening instead of the afternoon, they were flatly denied. A rebellion followed, but though some of the hot-heads went so far as to incur the peril of expulsion, Holley stopped short. After all, what he wanted was to get an education, and to him these minor issues were not important enough to justify the risk of losing that. So he declined to abet further the revolutionary movement with which he heartily sympathized, and turned his tumultuous feelings into the safer channel of a long, eloquent, and indignant letter home.

It was either before or just after his graduation that he wrote an elaborate essay on "Water Considered as a Carrier," which was published in 1854 in successive numbers of the *Litchfield Inquirer*. It is an exhaustive account of the functions and properties of water as a conveyer of gases, mechanical sediments, dissolved salts, germs, etc., in the vegetable, animal, and mineral kingdoms; of its agency in geological formations, volcanic eruptions, etc. Curiously enough water is considered as a carrier of every thing except heat. This aspect is omitted altogether, though it is the one with which the writer was at that time most familiar, and was afterward to be most largely concerned. The essay came from his reading, not from his experience. It is creditable to a young collegian; but still more creditable is the fact that he never wrote another like it.

In September, 1853, he was graduated, with the degree of Bachelor of Philosophy. His oration, on "The Natural Motors," is in point of style not notably different from the fervid and florid efforts common to such occasions. Yet it betrays throughout the passion of the speaker for locomotive machinery, terrestrial and marine; and two passages, describing respectively a locomotive and a steamship, show with what assiduous affection he has watched what he describes. Less clear and forcible is his allusion to electricity, the employment of which in the telegraph he represents with "commencement" rhetoric, as "ambitious man, grasping the red right hand of Jupiter!" But he pays a compliment to the

caloric engine, as an enterprise which "may yet be consummated in a future neither chimerical nor distant." This was just after the trial of Ericsson's steamer, and before the general recognition of the fact that heated air is useful and economical for small motors, though it cannot compete on a large scale with steam. I use the words of the distinguished inventor of the caloric engine—a man whose brilliant list of great successes renders him well able to afford the confession of a failure, and who, in the true spirit of science, has drawn from this disappointment grounds for gratitude. "The marine engineer," writes Mr. Ericsson, "has thus been encouraged to renew his efforts to perfect the steam-engine, without fear of rivalry from a motor depending on the dilatation of atmospheric air by heat." (*Contributions to the Centennial Exhibition*, 1876, p. 438.)

Holley's faith in the genius of Ericsson was confirmed in later years, in connection with the triumphs of the screw propeller and of the turreted iron-clad. And Ericsson's generous appreciation of Holley appears in a letter written since the death of the latter, and speaking of him as "the brightest ornament of American engineering."

After leaving college, Holley entered the shops of Corliss & Nightingale, at Providence. They were at the time engaged in the attempt to apply to the locomotive engine the principles of the variable cut-off, so successful in the stationary engine. Holley entered the locomotive department, where he served both as draughtsman and machinist, and subsequently took the "Advance" out on the Stonington Railroad, where he ran it as engineer long enough to show the practicability of so doing, and, I believe, to effect the sale of the engine. In economy of steam, as shown by indicator diagrams, the "Advance" was superior to existing link-motion and lap-valve locomotives, but the detach variable cut-off was too delicate an arrangement to endure the jar of such rough service. Another arrangement was substituted; but this, too, rattled to pieces; and even in the form finally adopted, the "Advance" was not practically a machine to be enthusiastically welcomed, particularly upon such road-beds as were then characteristic of America.

In his speech on "The Pursuit of Science," at the Hartford dinner of the Society of Mechanical Engineers, Holley revived his reminiscences of the "Advance." Said he:

"The idea began to obtain that science should be pursued not in books, but in things; and I commenced the pursuit of science in and on and under one of

the awfulest *things* this world ever saw. It was Corliss's original locomotive, euphoniously called, 'The Old Jigger.' This locomotive was possessed of a certain inborn cussedness, which could hardly be the attribute of a mere machine—her spiritual nature was a sort of Mephistophelian cross with a Colorado mule—and as to her physical constitution and membership, a cotton-factory 'mule' was simple in comparison. The Old Jigger had, as nearly as I can remember, 365 valves, one to break down every day in the year. And as a valve *motion*, well, nobody ever counted the number of its pieces. They were as the sands of the sea-shore. Most of them used to jar off, the first few trips of the week, after which all the men in the shop could comparatively keep track of the rest of them. I will say for the Old Jigger that she made the best indicator-card I ever saw from a locomotive; clean cut-off, almost a theoretical expansion curve, and an exhaust as if she had knocked out a cylinder head. Well, once in a while, after she had been jackassing over the road about four hours behind time, and we had pinch-barred her into the round-house, we used to pull out these indicator-cards of hers, and talk them over right before her, and we would look at her and ask one another why in thunder an engine that could make a card like that would act as if the very old—chief-engineer was in her. And next morning she would rouse up and pull the biggest train that had ever been over the road—ahead of time.

"But she was an inconstant old girl—and lazy, too—used to prefer to work with one side, and always made some plausible excuse for breaking down the other. I remember, one March morning, when nobody was looking, she kicked off about two dozen pieces of her starboard valve-gear, and brought up all standing, over a culvert about ten feet wide and full of ice-water. As I was standing in this culvert up to my middle, disconnecting her eccentric straps, a college professor came along, and rammed his umbrella into me, and asked me to explain to him the difference between this locomotive and any other locomotive! I then delivered my first scientific lecture; and I am now of opinion that its diction would have been modified by a divinity student!

"Continuing my pursuit of science, I left Corliss's works with a knowledge of valve-motion which was simply sublime; and I then proceeded to engraft this knowledge on a locomotive works in the Middle States."

So far, the dinner speech, delivered in May, 1881. How lightly does memory pass over the sad hours of the past! Probably the witty orator would have been as much startled as his hearers if any voice had recalled to him the period of despondency, through which he had passed after leaving the Corliss shop, and before finding employment elsewhere. Messrs. Corliss & Nightingale wrote, under date of March 27th, 1855:

"Mr. Holley has been employed for nearly eighteen months in the locomotive department of our business. He is an accomplished draughtsman and exhibits talent in the designing and application of machinery. During the time he has been with us, he has enjoyed every facility for becoming practically acquainted with the working of locomotives. We should be glad to avail ourselves of his services in our regular business of manufacturing stationary engines. But his mind is on locomotives; and therefore, into that branch of mechanism will he carry that spirit and aim that will insure success. As we do not propose to

pursue the locomotive business at present, Mr. Holley leaves us, and carries with him our best wishes for his success."

Armed with this and other introductions, he visited the principal locomotive shops of the West in search of employment, with the result stated in the following letter, written about a month later, in St. Louis:

"I am completely discouraged. I have applied at every place in the Western country where they build locomotives, except one (at Milwaukee), and I am informed that I shall find no opportunity at that place. At Detroit, my letters were of no avail. They wanted no draughtsman, only made the locomotive business a minor affair, and did not propose to try to establish a reputation of their own—as nearly as I could understand it. Mr. ——, of Cleveland, had no place for me, and said that if there was anything in the world he hated, it was patented improvements. Niles & Co., of Cincinnati, had a first-rate draughtsman, and would not change. * * * —— & Co., of Cincinnati, only build a few machines and hired a draughtsman, as they used a turning-lathe, for mechanical labor only. They get some poor fellow who will work a month or two, and then starve a month or two when they don't want to use him. The Covington, Louisville, and Chicago works have suspended. The shop at St. Louis is a good one; but they could give me no encouragement, though they seemed to be anxious to drive business. They have no draughtsman at all, and think that people here are too ignorant to desire any change in the old form, even though it might be an improvement. I even offered to work for almost nothing, at almost anything, if they would take me in, but was unsuccessful. * * * It is strange that when I have taken such pains to represent myself modestly, and am willing to do anything and work and persevere to the utmost extent, that when I have got such strong letters, and that when I know that I can build a better locomotive than all the rest of them put together—even in the face of all this, I cannot in the whole Western country get a place to earn my daily bread. The idea is damning to a man's spirits; though sometimes it looks so ridiculous that I cannot but laugh at the world generally. One thing is certain—I *will* build locomotives; and if my life is spared, I will ultimately place myself in a position where I can look down on every man who has neglected me, and laugh with a good will at the bad luck which the *improvements* they scorn have brought upon them. It may be a long time before I shall get my head out of water, and I sometimes fear that my spirit will fail me before I see the daylight. If I sink, poor and unknown, I honestly believe I shall drag down with me some ideas of which, however humble they may be, the world is not worthy. * * * I want to visit the Philadelphia, Baltimore, and New Jersey works, and see if I can convince myself and my friends that I am good for something. If I fail in doing this, I am ready to sink; for if there is anything certain in this world, it is that I will NEVER *do anything* permanently for a living but just this one thing, namely, building locomotives."

It was at the very end of his hopes—in the locomotive works at Jersey City—that he found employment at last. And it was while he was working there that he, most improvidently and most fortunately, married. It is not my purpose in these remarks, devoted

as they must be to his professional career and works, to intrude upon the sacredness of his domestic life. Yet the two are not altogether separable. There are those who have not forgotten how the young wife trudged daily with her husband to his experiments with coal-burning locomotives on the Harlem road, or assisted him in the office of the *Railroad Advocate*, or haunted the new Bessemer works at Troy, until he was accustomed to say, when fears were expressed for his health, "Don't be afraid; if I die, *she* can run the concern." More than this: from the date of his marriage we find in his letters no more outbursts of despair, but the cheerful and sanguine courage of a heart anchored in a happy home. Into that home, trouble and death came, as whither do they not come? But they could not banish peace and hope. Many of you will remember Holley's humorous and pathetic address at the Pittsburg banquet of the Institute of Mining Engineers in 1879. Replying to the toast of "The Fellows' Wives," he said, among other things:

"Young man of the school, full of lore and anxious for hire, what is the vista of probabilities that fills your eye? Will you map out the metalliferous veins under the fair landscape, from the ragged outcrops of the upturned rocks? Will you span the cañon, eroded throughout æons, with your gossamer steel bridge of yesterday? Will you compel a river which denudes a continent to build out its own ship-canal through its own delta with its own *débris*? Will you sever continents to make a highway for commerce? Will you coax out of ores with your deft alchemy the metals which the evolution of ages put in? Will you drive a train from the Orient to the Occident, following the sun, and keeping company with the hours? Ah, my dear boy! these things you may do; but they are only means to an end. And that end you shall see down the long vista of the inevitable. There, with eloquent eyes and folded arms, sits a dear little woman. And, my boy, when those tender arms shall enfold *you*, and those eloquent eyes shall flash into your soul the potential caloric of a whole life, then you will know what it is to be the lord of a fellow's wife. * * * Two thousand years ago, the philosopher Callimachus, wandering in the cemetery of Corinth, was arrested by a vision of prophetic beauty. It was only an acanthus plant confined in a basket and covered with a tile, the struggling leaves curling through the meshes and wreathing themselves in graceful volutes under the covering stone. This was the decoration of a child's grave; but it was the prototype of the Corinthian capital. As out of a little grave grew the glory of decorative art, so out of, ah! how many little graves, struggling through the meshes and repressed by the cold marble, perennially bloom the graces and the virtues of the higher life—that long-suffering, that patience, that elasticity, that sweetness, that association of the good and the beautiful, which is but another name for *the fellows' wives!*"

While yet at Corliss' works, Mr. Holley had written both for the *Polytechnic Journal*, and in Colburn's *Railroad Advocate* articles on the Corliss engines, which displayed marked ability. Probably it was this which brought him to the notice of Zerah

Colburn, the inconstant, erratic, unfortunate, but brilliant and wonderful engineer and author, whose fitful career would in itself be subject enough for a volume. Mr. Colburn had been superintendent of the New Jersey Locomotive Works, and had started in 1854 the *Railroad Advocate*, which may be said to have inaugurated a new era in the technical journalism of this country. From being a contributor to this paper, Holley became a partner and editor. The two men had many things in common. They were in love with the locomotive, and all that pertained to it. Their scientific knowledge had a foundation of practical familiarity with the topics of which they wrote. Colburn was the superior in the range and maturity of his professional knowledge, and it is impossible not to recognize the great advantage, intellectually, which his younger associate derived from this companionship. But in other respects, Colburn was no comfortable yokefellow. He could not bear harness. After a year, he sold out to Holley, and from April 19th, 1856, the *Advocate* was published by Holley & Co. In August of the same year, the name was changed to *Holley's Railroad Advocate*, though Colburn still wrote for it occasionally, and for about a year the burden, both of editorial and business management, was borne by Holley. His letters show that it was not light. In January, 1857, he writes that the paper is "filling up with advertisements at $24 an inch;" in February, he is still sanguine, but says that "like all other things, it is slow at first." He adds, "I must be traveling most of the time, and picking up all that is new, to keep up the interest in the paper, and must keep it full of advertisements. I cannot edit the paper in New York, or in any less space than several millions of miles." In March, he writes from Lynchburg, Va., that he has progressed slowly, but thinks the trip will be pretty successful. He will have some $300 worth of advertising from Richmond. The country is not so dilapidated as he expected to find it. Things are lax and dirty, but there is a good deal of enterprise in the larger towns. He expects to go on as far as New Orleans and Cuba.

The *Railroad Advocate*, caught in the storm of the great commercial crisis, was sadly battered, if not wrecked. It never fulfilled his hopes, as a business; but we cannot fail to see what an education for its proprietor and editor was furnished by this active and continuous association with men and things as well as books and literary labor.

Meanwhile, Colburn, after several unsuccessful ventures in other directions, returned to journalism. In July, 1857, *Holley's Railroad Advocate* became Holley and Colburn's *American Engineer*, and in the following September was suspended and never revived. The cause of the suspension appears to have been the "hard times" of 1857; but the ingenuity and energy of the owners made this the occasion of a new venture. Securing from a number of American railway presidents and from private friends the necessary means, they went to Europe, to study foreign railway practice and to report upon those features of it which would be most important at home. This was the first of thirteen journeys across the Atlantic, made by Holley, every one of which was fruitful of benefit to his country. No American ever went abroad more thoroughly furnished for such a work by nature and by training. If Colburn, on this first trip, showed him how to do it, he needed no teaching afterward.

It was on the return voyage that the *Ariel*, in which Holley was a passenger, was nearly wrecked, and obliged to put back. The following vivid description is taken from an unpublished fragment found in Holley's handwriting among his papers:

"We merrily sailed out of the Solent, past the Needles, against a stiffening breeze, just as eight bells sounded the New Year. But the barometer fell and the sea rose for six days, and on the tempestuous morning of the seventh, we were awakened by that joint sensation of ominous silence and new motion. The noisy but assuring heart-beat of the engine-room had stopped, and we were rolling over and over. The paddle-shaft was broken just outside the hull; one wheel was banging against the planking, and likely to go to the bottom with its counter-balancing weight; the ship was in the trough of the sea, and the gale had grown to a hurricane. They tried to make sail enough to get steerage-way, but the fore-yard snapped in two. Then the gallant Ludlow threw out a floating anchor called a 'drag,' a big basin, made of a stout and weighted sail, stretched on four spars. This, with our spanker, held her just so far out of the trough that we only got 'pooped' once—then came in the stern windows, and a foot of water over the cabin floor, washing away babies, furniture and—hope. I knew the engineer professionally, and I crawled down to his den, and begged him to let me do something to occupy my mind, for I was afraid. But he said there was little to do, except to keep the bilge-pump running, for she had sprung a leak. Then I crawled up into the cabin again, and saw some men crying and wringing their hands, and some dear women, brave and quiet, taking hold of each other's hands, and looking like angels. That took away my fear; and I made a sort of nest for some little children who were tumbling about with the *Ariel's* lurches; and I told them stories and worshiped their innocence and their ignorance of engineering which I had spent half a life to learn. So passed the dreadful day and night. We had no regular meals, of course; but the cook scalded some potatoes and himself; and a few of us went into his galley, cooked ourselves and some chops, and in that fun

we almost forgot our condition. The next day was Sunday. The hurricane had not abated. The pumps had simply kept the ship afloat. The greater number of the passengers wanted to have a prayer-meeting, and ask the Deity to stop the storm. There was no authorized representative on board, except a Catholic priest, and he was one of the best and truest men I ever met. He kneeled down in the cabin among us all, and, without any ritual or any Latin, he described our peril and our wants in a few graphic and fervent words, which put us in harmony with the situation. Then the storm broke, and the next morning was bright and sunny. For ten days, we sailed and paddled with our well wheel back to Queenstown."

Colburn and Holley's report—a handsome folio, with 51 engraved plates—appeared in 1858, under the title, *The Permanent Way and Coal-burning Locomotive Boilers of European Railways, with a Comparison of the Working Economy of European and American Lines, and the Principles upon which Improvement must Proceed.* This title is admirable, because it exactly expresses the three-fold nature of the work, which comprises a description of foreign plant and practice, a demonstration of American inferiority, and a recommendation of practicable improvements.

The book reflects much credit on its authors in many ways. With characteristic courage and ambition, they issued it in a style which they could ill afford, and which makes it even to this day one of the handsomest of engineering books. It was a bold venture, even outwardly, and its contents were bolder yet. When we remember that Colburn and Holley were abroad less than three months, collecting the materials for it, we are astonished at its completeness and accuracy. They were "tremendous workers." Holley's letters show that after a few days given to the new delights of travel, and the sights in London, he settled down to intense labor, visiting railway shops and offices, and devoting days and nights to writing and drawing. The excellent descriptions thus prepared, might, however, have fallen unnoticed in the presence of a public little able to appreciate mere engineering details. It was the "Comparison," made by Colburn, which appealed directly and irresistibly to American railway managers—"counting-room engineers," as Holley was wont contemptuously to call them—with its overwhelming demonstration of the financial economy of the best construction and the best machinery. In 1860, Holley wrote:

"The first half of the last decade was distinguished by the *opening*, as if by magic, of thousands of miles of railway; the last half has been distinguished in revealing the fact that the roads thus open are yet to be built."

This revelation was effectually made by Colburn's "Comparison."

It was not enough to show that the annual operating expense of American railways was $120,000,000 against $80,000,000 for the same mileage in England—an excess of $40,000,000; that the annual maintenance of the road-bed cost $33,000,000 here, against $12,500,000 there—an excess of $20,500,000; that the cost of fuel was $18,000,000, against $7,500,000, thus giving as total expenses, $171,000,000 in America and $100,000,000 for the same mileage abroad. Any industrious compiler could present such figures; and the counting-room answer was ready. "Such comparisons could not be made. The conditions were utterly different in the two countries. English lines are very expensively built, and what was saved in current expense was paid out in interest on first cost. The grades were lighter than ours; the traffic was more favorable; there was cheap fuel and pauper labor." This sort of vague *qualitative* talk is what all reforms encounter; and it must be met with *quantitative* demonstration. In all such questions there is "truth on both sides;" but the scientific inquirer weighs the truth, and ascertains on which side is the ultimate overweight. In this case, Colburn proceeded to discuss in detail all the varying conditions, and to give a precise value to each. He showed that of the superior English economy of nearly 60 per cent. in the maintenance of permanent way, only about half was due to favoring circumstances; that of the 44 per cent. superior economy in fuel, only 15 per cent. could be thus explained; that the necessary difference in first cost was far less than had been supposed. By an exhaustive analysis, he tracked the saving to its sources, and proved these to be chiefly the locomotive and the permanent way. This was an argument which financiers could understand. The press took it up, and drove it home. The leading New York dailies came out with long leaders (mostly contributed by Holley) on the causes of the depreciation in railroad property, and drew from this book overwhelming proofs. The English press, of course, rejoiced in its acknowledgment of English superiority. Even the patriotic rage displayed by some of our journals, regarding this conceited attack on American institutions, helped to advertise the book. Taken together with its successor, Holley's *Railroad Practice* (of which I will speak presently), it inaugurated and did much to effect a revolution. As to the completeness of the mechanical part of it (which was Holley's special portion), I may here quote a remark once made to me by a leading railway engineer of this country. Said he, "I keep the book in my office still; and frequently when

inventors call on me with their new ideas about rails, and joints, and sleepers, and boilers, and so on, I open Colburn and Holley, and show them their inventions, already described and discussed."

From Holley's letters during 1858, it is evident that he traveled extensively, soliciting subscriptions from railway companies to cover the cost of publishing the report, and also selling other scientific books on commission to cover his expenses. Probably during this period he made the acquaintance of Mr. Henry J. Raymond, founder and editor of the New York *Times*. His first article in that paper was a vigorous editorial on railway management, published November 9, 1858.

Mr. Raymond was characteristically quick to recognize, encourage, and attach to his corps of editors, reporters, and correspondents young men of talent and ambition He realized that he had found a prize in Holley, who speedily became a frequent contributor to the *Times*. I have found 276 articles from his pen, published in that paper, of which about 200 appeared between 1858 and 1863, and the remainder at rarer intervals to 1875, the last being the leading editorial of April 27, 1875, on the recently appointed United States Testing Board. The range of these articles is indicated by the following classification: Setting aside 52 miscellaneous articles (descriptive, political, etc.), and 30 which may be called "scattering," though devoted to engineering topics, we have 194, divided as follows: Railways (including street railways), 49; steam navigation, 42; war ships and armor, 30; the Stevens battery, 22; arms and ordnance, 19; boiler explosions, 11; and steam engines, 7. The most important and remarkable of these articles were, perhaps, those on the *Great Eastern*, written under the signature of "Tubal Cain." In 1859, he accompanied Mr. Raymond to Europe as a *Times* correspondent, made the acquaintance of Brunel and Scott Russell, and thoroughly studied the structure and details of the great ship. His description (October, 1859) of the vessel and its machinery (accompanied with drawings), his account of the trial trip, the accidental explosion occurring on that occasion, the coroner's inquest, etc., and his discussion of various engineering and commercial questions thus suggested, present a wonderful combination of technical, critical, and literary skill. The articles attracted attention on both sides of the Atlantic, and the *Times* assumed a position of authority on engineering topics not before or since occupied by a New York daily newspaper.

In 1860 Holley again went to Europe for the *Times*, and re-

turned on the first transatlantic trip of the *Great Eastern*. This time his equally remarkable letters were divided between the *Times* and the *American Railway Review*, of which in the meantime he had become editor of the mechanical department. The *Review* was a New York weekly. His connection with it began with its second volume, in January, 1860, and lasted about eighteen months. Among the first things he contributed to it was a description and explanation of the Giffard injector, then a novelty. An examination of the columns of this paper and of the *Times* throws an interesting light on the manner in which he contrived to do so much literary and professional work. He made one hand wash the other. The topics treated for the general public in the *Times* were served up in more technical form in the *Review*. The anonymous editor in the *Times* frequently quoted and commented upon the avowed editor of the *Review*, and *vice versa*. But all this was merely the incidental, though necessary, occupation of this period. He wrote to earn money, and he wrote with the rapidity and versatility of a Bohemian; but all the time his eye was upon his profession, and his articles were but the chips thrown off in the labor of preparing his "American and European Railway Practice," which appeared at the close of 1860. This was, so far as the subject of permanent way is concerned, a digest of the report of Colburn and Holley, but it was a great deal more. The subjects of the combustion of coal, its use in locomotives, the economical generation of steam, the proper construction of boilers, etc., were thoroughly discussed, and the whole problem was treated with the precision of a judge combined with the earnestness of an advocate. The defects of American railway management in these particulars were exposed with satire and indignation. The book was, in even a higher degree than its predecessor, an epoch-making one. Our railway practice in the branches of which it treats has done little more than follow its guidance, and its recommendations and warnings are not yet out of date.

In the preface to this work, Holley acknowledges assistance received from Mr. J. K. Fisher, well known to New Yorkers as an engineer of talent and an inventor who tried hard—and failed—to introduce steam carriages on common roads. In the latter experiment, Holley gave him some professional and financial assistance. The money was lost; but out of this, as out of all other experiences of his life, he drew a dividend of added knowledge. I believe he never ceased to consider the steam carriage and traction engine as

technically an accomplished success, and certain eventually to find a wide use in this country. To discuss the causes which have falsified, thus far, that expectation, and have left us apparently more distant than ever from its fulfillment, would be beyond the limits of this occasion. Suffice it to say, that, in my judgment, the immense extension of railroads is one of them.

Another matter to which Mr. Fisher had given great attention was that of steam fire-engines. How quickly and thoroughly Holley appreciated this problem may be seen in several of his *Times* articles—notably a long one, published December 10, 1858. It is a model of clear and epigrammatic statement, abounding in such sentences as these:

"The size of a fire-engine is limited by the size of the men who handle the hose. We can build an engine that will throw a river over a mountain—*who will hold the butt?*" * * * *

"Boilers which can raise steam from cold water in three minutes can do almost anything else in the next three minutes, if they are not closely watched."

There is ample evidence that the outward rewards of all his labors so far had been mainly in growing reputation, not in money. He was still struggling for a living. In April, 1859, he took out two patents, one for a variable cut-off gear for steam-engines, and the other for railway chairs.

Of the railway-chair patent he writes at the time, "My rail-joint seems to be liked; and I shall doubtless make something out of it." It preserved the continuity of the rail ends by brackets, so attached to the spliced pieces and tension plates that the weight of the wheels of the train on the rail kept the splices tightly in their places, without the aid of plates, nuts, keys, or rivets. It was illustrated in his *Railway Practice*, and in the *Railway Review*. It was tried by one or two roads (I believe with satisfactory results); but it did not come into wide use, partly, as I judge, because reforms in rail-sections and permanent way made the simple fish-plate adequate to all demands. As Holley wrote in the *Review*, "The practical difficulty with the fish-joint is not the form of the fishing-piece, but the form of the rail."

Meanwhile, the pressure of outward necessities continued, but Holley's courage and hope rose to meet it. The denser the medium through which he made his way, the greater his relative buoyancy. In March, 1861, he writes:

"I have an engagement with the publishers of 'Webster's Unabridged Dictionary,' to write a lot of engineering words and definitions, to make some illus-

trations, and to correct engineering definitions, for a new edition of that work, for which I get my name put in the book, and two hundred dollars. The former part of the pay will be pretty valuable, and the latter part very timely in these awful days of panic and poverty. I am at work at this as hard as possible, to get it done in time, and to get the money."

A few days later, he writes, referring to the slow sale of his book, and other difficulties:

"These unexpected hard times have certainly and *fairly* interrupted my plans. Under normal circumstances, things would have come out as I expected they would. Therefore, I do not think it bad management, but bad luck, that I am still in an undesirable position. But I am making my expenses as light as possible, and getting what professional work I can do. I yesterday completed an arrangement with the Camden & Amboy Railroad Company, to alter an engine of theirs to burn coal. I am to be paid eight dollars per day, and to be employed thirty or forty days. Mr. Stevens, the president, has been for some years engaged on a battery for the government, about which you know, of course. He says he shall probably be called on to finish it by this administration, and that he may want to employ me, here and in Europe, for this and other matters. I am also getting some business as an expert, which pays first rate—am writing for the dictionary, and gradually getting the business offered, after which I have so long been seeking. So, on the whole, I do not despair of getting back the money I have been investing for the last ten years in *education*, and of securing something to live on."

Up to this time I find no proof that Holley interested himself specially in politics. He seems rather to have regarded with disgust the manner in which the slavery question, in one form or another, engrossed the attention of Congress, leaving great matters of internal improvement, the regulation of commerce, the safety of travel, the construction and maintenance of public works to be dealt with by crude and hasty legislation. Thus he writes, in the *Times*, May 3, 1860:

"As the law-makers tread the decks of steamers, they will need no expert to unfold the probable causes of danger. Let them but look and tremble; a single compartment with a wooden shell—heaven only knows how weak and rotten—quivering with each stroke of the engine—between them and death; fires roaring and lamps swinging within the very embrace of seasoned combustibles—boiler-plate of questionable tenacity, straining under undue pressure—fire-pumps and hose, bilge-pumps and life-boats, lashed and stowed away for the voyage like so much cargo or permanent ballast; sailing vessels, without light or signal, bearing down into our very path; should such danger overtake us, what are the probabilities of deliverance? The chances are, that there will be a collision—that a hole in any part of the hull will admit the sea to every cranny of the fabric; that the furnace-fires will be quenched before the steam-pumps can be set at work; that the ship will founder before all the boats can be cleared and launched; that all the boats will not hold half the people; that there is no material for rafts; that the vessel will take fire; that the fire will

get the advantage before the pumps can be got at work and the hose adjusted; that the deficient means of overcoming danger, and especially the delay in applying the means provided, will give accident and carelessness the winning start of defense and caution.

"Urgent and reasonable as are the demands of the case, it is found practically impossible to meet them fully and fairly with legislative enactments. Sectionalism, State rights, spoils, corruption selfishness, and the whole catalogue of personal and party motives and influences, menace alike the interests of the white man and the negro—the African traveler and the Red River slave."

Like the vast majority of our citizens, he did not realize the serious and instant peril of the country. As late as March, 1861, after the inauguration of Lincoln, when the government of the Southern Confederacy under Jefferson Davis had been fully organized, Holley became a candidate for the position of U. S. supervising inspector of passenger steamers. The letters forwarded in recommendation of his appointment to the President were subsequently returned, and after his death I found them among his papers. I do not wonder he preserved them. They constitute an astonishing testimonial to the professional standing of a man not yet thirty years old. A host of firms and individuals, including the presidents and engineers of the principal American railways, and the managers of great shops for the construction of steam machinery, bear witness to the extraordinary ability and fitness of Mr. Holley. If I repeat before this audience the names of J. Edgar Thomson, Erastus Corning, John Taylor Johnston, Sam'l Sloan, Charles Minot, Allan Campbell, S. W. Roberts, Amasa Stone, John C. Cresson, W. H. Clements, David Hoadley, George H. Corliss, J. S. Rogers, M. W. Baldwin, Richard Norris, W. W. Fairbanks, Horatio Allen, Benjamin F. Thurston, Peter Cooper, Abram S. Hewitt, Edward Cooper, J. G. Barnard, William G. Hamilton, Cyrus W. Field, Samuel J. Reeves, Montgomery C. Meigs, to say nothing of College and West Point professors or editors like Henry J. Raymond, and personal friends of the President and cabinet, I need add nothing to prove the unusual force of these credentials. In a private letter dated April 3d, 1861, Mr. Holley says:

"I was in Washington the other day, about the inspectorship, but I do not expect to get it. I have as fine a list of engineering names as could be offered; but I have no hard-working New York City political backers, except Mr. Raymond. Another candidate is more of a politician than an engineer, and he will probably get the place. However, I may get it. I shall certainly *not* go and bore the President and departments. If they can't take my papers as evidence, they ought not to take my own statement."

Those who remember him in the brightness of his youthful prime cannot but feel that his personal application, adding magnetism to the weight of his professional indorsements he presented, would not have bored even the tired officials at Washington, but would have inspired them with the desire to win for the public service his skill and enthusiasm—would have enabled them to find delight in duty. But it was not thus to be—and so far as we can now discern, what was to be was better.

The letters of those gentlemen I have named, with many others, were subsequently recovered from Washington, and arranged and filed by Mr. Holley. On a blank page at the end, he wrote in his bold hand these significant words: "What came of it? Mr. Holley was not appointed." Yet through all his life he was proud of the indorsement he had thus received; and to-night we may safely say that those who gave it need not be ashamed.

Besides the ordinary fatuity which presides over governmental appointments, and the special pressure of party politics in the case of a new administration, receiving the powers and privileges of federal office for the first time from the hands of its party opponents, there were in this instance peculiar reasons for the apparent neglect of Holley's application. Events were then occurring which might well cause those in power to overlook the inspectorship of steamboats. The attention of all was concentrated, not upon the possible accidents that might occur to vessels navigating the Hudson or the Sound, but upon the events then taking place in the South. The firing upon our flag in Sumter and Baltimore excited to the highest pitch the feelings of the North. Many of you must remember the scenes that transformed the metropolis: the vast meeting at Union Square, with its many platforms and orators, and its surging, shouting multitude of hearers and spectators. What enthusiasm attended the passionate appeal of Mitchell and Baker, as they pledged their lives to the service—pledges redeemed by both, after a few short months, in blood! And what a frenzy of applause followed the reply of one of the orators, when being asked from the crowd, "How about the Seventh Regiment?" he answered, "They have just been heard from by telegraph at Philadelphia. It is proposed that they go by sea to Washington; but *they prefer to march through Baltimore!*"

The sudden change in the sentiments of many who up to that time had hoped for compromise, is well illustrated in the case of Holley. In January, 1861, he had written:

"I suppose we have got to have a war; but it is a pity to fight for what isn't worth fighting for. It seems our duty to have a general convention of the people and let the beggars go."

But the events of the next three months were for him, as for the majority of his Northern countrymen, a rapid political education, and on the 23d of April, 1861, he wrote to Secretary Chase the following letter, substantial duplicates of which were sent to the War and Navy Departments also:

"I am an applicant, indorsed by a large number of prominent engineers, for the office of United States Supervising Inspector of Steamers.

"In the present state of affairs, I am anxious to bring such engineering facilities as I may command into the service of the Government.

"I have an intimate acquaintance with Mr. Scott Russell and many other English engineers and ship-builders, having been sent to Europe several times on engineering business.

"If I can do the Government any good with reference to the construction or purchase of ships or arms, the construction of batteries, gun-boats, or iron vessels of light draught, the application of armor to ships, etc., I hereby offer my services, *without compensation*, desiring only that my necessary expenses be paid, as I have not the money to pay them.

"I know that I have peculiar facilities for gaining the latest information relative to the construction of iron ships and boats and their engines, without waste of time.

"I refer you to the names appended to my application aforesaid. I am ready at an hour's notice."

On the same sheet, Mr. Raymond added these words: "I know Mr. Holley *intimately*, and KNOW him to be in every respect one of the very best men whose services the Government can command.

From another source, I learn that at this time Mr. Holley was ready—as what patriotic young American was not?—to enlist in the Army or Navy, but that a little reflection convinced him of the greater usefulness which lay in his professional skill.

The letter I have quoted was filed at the Treasury Department (as the clerical indorsement upon it shows) together with the other papers concerning Mr. Holley's previous application for office. Neither it, nor the similar letters addressed to the Navy and War Departments, were ever acknowledged. Probably there was no time in those crowded days for mere politeness and thanks. Probably thousands of other men were tendering their services, even without pay. Moreover, experienced administrators know very well that the acceptance of such gratuitous service is in most cases no advantage to the public. Officers under salary, and no

others, can be held to strict responsibility. The honorary employees of the State demoralize the rest. They despise red tape, which is, on the whole, essential, however harmfully it may now and then be tangled; and, to speak plainly, no tangle is so mischievous as that produced by a volunteer shuttle, flying lawlessly across the web of a regular system. Railroad engineers know how many trains must be delayed when some swift "special" demands the track, in spite of the time-table.

Doubtless these calm considerations did not comfort the soul of the ardent young volunteer, conscious of the power he freely offered to his country. There is a touch of bitterness in the words indorsed upon the papers I have quoted: "What came of it? The letters received no attention. The foregoing application to Secretary Chase was found filed with the application for the Inspectorship, at the Treasury. The End." To which, indeed, History adds, "Not the end, but the beginning."

Both his patriotism and his professional ability found an immediate object in the Stevens battery, and in other plans which Mr. Edwin A. Stevens proposed to the government. That remarkable man and his brother, Robert L. Stevens, were the originators of most of the modern improvements in naval warfare. Their father, Col. John Stevens, built in 1805 a steam-vessel with twin screws—a feature adopted in the Stevens battery, and in the *Naugatuck* (a vessel presented the U. S. Treasury Department during the war by Edwin A. Stevens), and subsequently employed in the war-ships of England. The armored iron-clad known as the Stevens battery was proposed by the brothers Stevens to the United States Government as early as 1841. It was not until 1854 that the work was commenced; and in 1861, twenty years after its suggestion, it was still unfinished, the Government having refused for more than eighteen years to do anything about it. Half a million of public money had been spent upon it; Mr. Stevens had spent $200,000 besides; and he now asked from Congress an appropriation of $500,000 to finish the whole work. The proposal met with unexpected opposition. Holley states the case in a *Times* editorial, August 13, 1861, as follows:

"Here is an iron screw-ship of 6,000 tons, made of the best selected material, with as beautiful a model as ever floated, with engines and boilers of a pattern superior to that of most modern steamers, and capable of developing the whole horse-power of the *Great Eastern*, and a speed of twenty miles an hour—a ship that can turn on her own center in perhaps a minute—outrun any known enemy, fire with her eight guns a heavier broadside than the *Warrior*—fire three of these

guns at a time parallel to the keel—sink to the gun-deck during the action, and so only leave her cover, as it were, to be protected by plates—carry 6½ inch armor, inclined at 30°, and coal enough to cross the Atlantic at ordinary speed—a ship up to the best commercial practice in every important detail, and ahead of the best naval practice in nearly all—and this is the vessel that some of our contemporaries advise the Government to abandon as a *failure*, while Congress debates bills for the construction of *modern* iron-clad ships!"

It is impracticable on this occasion to trace the course of the discussions, examinations, reports, negotiations, and intrigues which constitute the subsequent history of the Stevens battery. Holley's work, in connection with it, turned out to be rather literary than technical. Mr. Stevens, whose age and health disinclined him to engage actively in a fight for the privilege of serving his country with his knowledge and experience, left this part largely to Holley, who wrote memorials, arguments, criticisms, editorials, with untiring zeal, bringing to bear science, wit, eloquence, and anger in a manner peculiarly his own. Whatever may be said of Stevens' battery, Holley's battery was unquestionably a powerful one; and, so far as words could win the battle, he won it. But the victory cost too much time, and when won, it was fruitless.

The peculiar features of the Hoboken ship have been elsewhere adopted, and in turn superseded. The principal effect of this episode upon Holley's career was the attention it caused him to give to the subject of ordnance and armor.

Sent abroad in 1862 by Mr. Stevens to investigate this subject, he found the facts he needed scattered in official documents, monographs, unpublished records, etc., and speedily his own note-book became a more comprehensive and accurate collection of them than any printed book. He obtained his information with some difficulty. I find, for instance, the following letter from his friend, J. Scott Russell, referring to certain ordnance works or experiments of the British Government:

"My Dear Holley: "Sept. 24, 1862.

"I have applied in the proper quarters, and find that special instructions have been given that *you* are to be refused admittance.

"As you have achieved this distinction, you will, I am sure, have no wish to put yourself in a false position. * * * Yours sincerely,

"J. Scott Russell."

On another occasion, Holley desired to study the lines of a new British iron-clad, then in process of construction. One of the contractors, whom he had made (as usual) first an acquaintance and then straightway a friend, said to him, "If you can manage to get

into the yard, I will show you all you want to see. But I am powerless to procure admission for you, and I am sure it will be refused if you ask it." It must be admitted that in spite of the confidence of his friend, Mr. Scott Russell, Holley did, on this occasion, "place himself in a false position;" for he hired a stylish carriage, arranged himself in solitary state with folded arms on the back seat, gave the necessary instructions to the coachman, and drove straight through the big gate in the yard, acknowledging with a bow the presented arms of the guard, as proudly as any other Lord of the Admiralty. Once inside, he found his friend, and satisfied his curiosity. This story, now published for the first time, is respectfully dedicated to her Majesty's Government!

We can hardly wonder at the occasional exclusion of Holley from important works at that time. He was certain to send to his own government whatever new facts he observed. On the whole, however, he was treated with liberality, and his note-book became, at the close of 1864, a treatise on Ordnance and Armor.

This work has, perhaps been overrated. It is in reality a clever piece of book-making, remarkable as showing with what rapidity and accuracy a trained reporter, employing both pen and pencil, can collect and arrange a mass of data. Holley's independent criticisms and suggestions are not made prominent; though, when they occur, they are sensible and timely. The book is simply an attempt on his part to supply the need which he had felt on approaching the subject of ordnance and armor—the need of a summary of the existing state of the art. It was translated into French, and became everywhere a recognized authority—just as a dictionary or a directory is recognized authority, particularly if it is large and thorough, and intelligently arranged, and the only one to be had. It is out of date now. The arts of warfare have made great progress since it appeared; and though it is still indispensable as a record, it is, to me at least, chiefly interesting as a specimen of Holley's method of work; his ability to grasp the leading principles of any mechanical problem; the facility with which he seized the details of an apparatus or an experiment, putting them down for future reference in words or in sketches, as might be most convenient; and the system with which he indexed everything he had once noted, so that he could at any moment recur to it again without delay.

While he was thus studying ordnance and armor, the columns of the *Times* coruscated with brilliant articles from his pen on these

topics, and the bureaus at Washington had frequent reason to regret that his genius was not directly enlisted in their assistance, instead of employing the free lance of destructive criticism.

An interesting and able summary of this subject appeared in the *National Almanac* of 1863, under the title, "Iron-Clad War Vessels;" and the *Atlantic Monthly* of January, 1863, contained an article from his pen on "Iron-Clad Ships and Heavy Ordnance." At the close of this article, he speaks of a more extended work, about to be published by Van Nostrand, of New York, thus showing that at that time Ordnance and Armor was almost completed, though it did not publicly appear for nearly two years.

Before it saw the light, his activity had turned into a new and still more important channel. In May, 1863, he writes:

"It is a matter of regret to me, on many accounts, that I have to go to England again this summer; but this is no pleasure trip, but a trip preparatory, I hope, to something settled. Precisely what I am going for, I am not at liberty to say except that I am going to get information for Corning Winslow & Co., about a new manufacture. If I succeed, they are going to establish the business, which will be in nature allied to, but in a business way separate from, their present manufacture. They then wish me to become a partner in the new business. * * * and expect, if I succeed, to spend about $30,000 in establishing the new manufacture."

Imagine starting in the Bessemer business with $30,000!

His mission was successful. The Bessemer patents were purchased, and subsequently combined with the conflicting American patents of Kelly. The works at Troy were built and started in 1865, and enlarged in 1867. From this time on, the career of Holley was substantially the history of the Bessemer manufacture in the United States. In 1867, he built the works at Harrisburg. About a year later, he was recalled to Troy, to rebuild the works there, which had been destroyed by fire. Still later, he planned the works at North Chicago and Joliet, the Edgar Thomson works at Pittsburg, and the Vulcan at St. Louis, besides acting as consulting engineer in the designing of the Cambria, Bethlehem, and Scranton works.

It is not my purpose to describe in detail the improvements he introduced into the Bessemer plant. They have been admirably summarized by Mr. Robert W. Hunt, in his paper (Trans. Am. I. of M. E., Vol. V., p. 201) on the History of the Bessemer Manufacture in America. It is fair to say that they put an entirely new face on the commercial relations of that manufacture, by enormously increasing its productive capacity, and proportionately decreasing

its cost. Whoever would appreciate their nature and effect, need do but two things: First, compare the pictures of the Bessemer plant and its arrangement, as given in English text-books and journals of that period, with the plans of American works; secondly, compare the records of foreign works with the records of our own. Mr. Hunt says:

"The result of his thought gave us the present accepted type of American Bessemer plant. He did away with the English deep pit, and raised the vessels so as to get working space under them on the ground floor; he substituted top-supported hydraulic cranes for the more expensive counter-weighted English ones, and put three ingot cranes around the pit instead of two, and thereby obtained greater area of power; he changed the location of the vessel as related to the pit and melting-house; he modified the ladle-crane, and worked all the cranes and vessels from a single point; he substituted cupolas for reverberatory furnaces; and last, but by no means least, introduced the intermediate or accumulating ladle, which is placed on scales, and thus insures accuracy of operation by rendering possible the weighing of each charge of melted iron, before pouring it into the converter. These points cover the radical features of his innovations. After building such a plant, he began to meet the difficulties of details in manufacture, among the most serious of which was the short duration of the vessel-bottoms, and the time required to cool off the vessels to a point at which it was possible for workmen to enter and make new bottoms. After many experiments, the result was the Holley vessel-bottom, which, either in its form as patented, or in a modification of it as now used in all American works, has rendered possible, as much as any other one thing, the present immense production."

Concerning the increasing productiveness of the American Bessemer plant, it may be said in round numbers that it has been raised from the capacity (per two converters) of about 900 tons per month to more than 10,000 tons for the same period—an exceptional maximum of over 14,000 tons of ingots in a single month having been reached by the Edgar Thomson works. Holley's arrangement of buildings and machinery, to secure convenience in handling materials, and his movable converter-bottom and other devices to reduce the time lost in repairs, were undoubtedly the basis of this great advance, though valuable contributions have been made by the able engineers who followed his lead.

But turning for a moment from technical details, I cannot forbear quoting from an article written by Holley, in 1865, for the Troy *Daily Times*, the description of a Bessemer "blow" at night. It is not only admirable in itself, but interesting as a proof of his keen perception of the picturesque and artistic elements in his profession:

"The cavernous room is dark, the air sulphurous, the sounds of suppressed power are melancholy and deep. Half-revealed monsters with piercing eyes

crouch in the corners, spectral shapes ever flit about the wall, and lurid beams of light anon flash in your face as some remorseless beast opens its red-hot jaws for its iron ration. Then the melter thrusts a spear between the joints of its armor, and a glistening, yellow stream spurts out for a moment, and then all is dark once more. Again and again he stabs it, till six tons of its hot and smoking blood fill a great caldron to the brim. Then the foreman shouts to a thirty-foot giant in the corner, who straightway stretches out his iron arm and gently lifts the caldron away up into the air and turns out the yellow blood in a hissing, sparkling stream, which dives into the white-hot jaws of another monster—a monster as big as an elephant, with a head like a frog, and scaly hide. The foreman shouts again, at which up rises the monster on its haunches, growling and snorting sparks and flame.

"What a conflict of the elements is going on in that vast laboratory! A million balls of melted iron, tearing away from the liquid mass, surging from side to side, and plunging down again, only to be blown out more hot and angry than before—column upon column of air, squeezed solid like rods of glass by the power of five hundred horses, piercing and shattering the iron at every point, chasing it up and down, robbing it of its treasures only to be itself decomposed, and hurled out into the night in roaring blaze.

"As the combustion progresses, the surging mass grows hotter, throwing out splashes of liquid slag; and the discharge from its mouth changes from sparks and streaks of red and yellow gas to thick, full, white, howling, dazzling flame. But such battles cannot last long. In a quarter of an hour, the iron is stripped of every combustible alloy, and hangs out the white flag. The converter is then turned upon its side, the blast shut off, and the recarburizer run in. Then for a moment the war of the elements rages again; the mass boils and flames with higher intensity, and with a rapidity of chemical reaction, sometimes throwing it violently out of the converter-mouth; then all is quiet, and the product is steel—liquid, milky steel, that pours out into the ladle from under its roof of slag, smooth, shining, and almost transparent."

It is scarcely possible to exaggerate the importance, to this country and to the world, of the Bessemer manufacture, and particularly of that manufacture on the vast scale which Holley's improvements helped it to assume. The end is not yet. The structural uses of steel are still in their infancy. But in one branch of engineering—the branch of Holley's early choice and love—a world-shaking revolution has been accomplished. The permanent way of which he wrote so much has received its final perfecting touch in the steel rail—and cheap transportation has been the result. The farmers and cattle-breeders of Great Britain find themselves brought into competition with regions of the very existence of which they had scarcely heard before. The invention of an English chemist, perfected and applied in America, reacts upon the whole social fabric. The gigantic specter of the land question itself reveals through its dread garments a skeleton of Bessemer steel!

To Holley personally, the entrance upon these new labors was the greatest change of his life. His chance, for which he had so patiently waited and so thoroughly prepared himself, had come at last. His work changed from the critical to the creative; and a whole side of his genius, repressed hitherto, sprang into joyous power.

All his life he had been fond of designing. The fertility of his imagination and his artistic taste were shown in a thousand ways—in the drawings with which he adorned albums and scrap-books; in the design he made for the charter-oak chair of state, which still wins admiration in the Capitol of Connecticut; in his love of old cathedrals and masterpieces of painting and sculpture. But he was not bewitched by the surface of beauty alone. Looking below the surface, he recognized the beauty of adaptation. He recognized the great scientific truth that the line of economy is the line of grace. The arch, the truss, were no unmeaning forms to him. And beneath a strong, light roof, or before a well-designed machine, or in the midst of a well-arranged plant, he found the satisfaction of an artist as well as an engineer. I think he took more pride in the Edgar Thomson works than in any other which he helped to build, because, as he once said to me, he began at the beginning with them, taking a clean sheet of paper, drawing on it first the railway-tracks, and then placing the buildings and the contents of each building with prime regard to the facile handling of material; so that the whole became a body, shaped by its bones and muscles, rather than a box, into which bones and muscles had to be packed.

Yet this new activity was not substituted for the older ones; it was rather superadded to them. In January, 1869, he took charge of Van Nostrand's *Eclectic Engineering Magazine*, which he edited for a year. In August of that year, he wrote from Troy:

> "I have not got along far enough in life to look back on much work or much fruit from it; but I have lived long enough to conclude with certainty, that leisure is the hardest thing in life to get along with. I try to have as little of it as possible."

In the subject of technical education, as I need not tell the members of these societies, he was deeply interested. Elected in 1865 a member of the Board of Trustees of the Rensselaer Polytechnic Institute, he made his influence felt in favor of an improved curriculum, keeping pace with the demands of the times. While it is impossible to discuss at this time the views on technical education which he subsequently announced, it is worth mention, in passing,

that the system he so eloquently advocated, of a practical training preceding the scientific instruction, was not the one under which his own genius had developed itself. He went from the school to the shop, not from the shop to the school.

If I pass swiftly over the latest and most fruitful years of his life, it is not because I fail to recognize their importance. They were in every way his best working years. His rapidly growing fame, his widening circle of friends, his own matured power, combined to give value to his labors, and to win for them adequate reward. In fact, this is the answer to those impetuous ones who think it better, as they say, "to wear out than to rust out," and declare that if they do twice as much, and live only half as long, the world at least will be no loser. This is not true. A true man's last work is his best. Two bushels of green apples to-day are not the adequate substitute for one bushel of ripe ones, when Time shall have brought them to perfection. And this ripening effect of Time is in human character the one thing that cannot be hurried. Wisdom —the degree conferred upon faithful students in the University of Life—cannot be had in the sophomore year.

But the work of these wisest and intellectually strongest years of Holley's life, is, for the most part, either familiarly known to all of you, or it is still under the lock and key of his professional relations, in confidential reports. His papers and addresses in the Institute of Mining Engineers, of which he became a member in 1872 and President in 1875, the Society of Civil Engineers, of which he was a Vice-President, in 1876; the Society of Mechanical Engineers, of which, together with the honored chairman of this meeting he was the founder, and the British Iron and Steel Institute, and Institution of Civil Engineers, of which he was a member; the admirable paper on "Iron and Steel," contributed by him to the Reports of the Judges of the Centennial Exposition in 1876; the series of illustrated articles on American iron and steel works, prepared by him together with Mr. Lenox Smith for London *Engineering* from 1877 to 1880; his masterly treatise on "Steel," published in 1880 in Appleton's Cyclopædia of Mechanics; and, in another sphere, his breezy description in *Scribner's Monthly* for May, 1878, under the title "Camps and Tramps about Katahdin," of a health-giving summer excursion, in genial artist company, to the forests and mountains of Maine—these are both familiar and accessible to you all. But more voluminous, and in many respects still more valuable, were the reports which he printed and issued confidentially to his

clients (for the last five years to the members of the Bessemer Association only) on the various branches of steel manufacture. No doubt when the immediate business value of these reports shall have passed away, they will become accessible to engineers generally; and they will be found a mine of clear, precise, well-arranged, and well-discussed information. I know that he regarded them as his best work, and that he put his life into them.

Of all the later labors to which I have alluded, and of other works of his pen, I shall publish as an appendix to this address a catalogue,* which I believe is complete, and which in itself constitutes a striking picture of his intense and various industry.

It was probably about 1875 that his elastic strength began to fail. In that year he wrote: "I have been so hard at work for so long that I am getting pretty tired and played out. I am going in a week to one of the Elizabeth Islands, off New Bedford, where there is neither mail nor telegraph, to lie on the sea-shore for a week, and try to get strong and *sleepy*." That last word tells the story.

In June, 1875, he was appointed a member of the United States Board for Testing Structural Materials. He had been unweariedly active in promoting the formation of this Board; he was not the least laborious of its members; and, down to the end of his life, he ceased not to strive that his work, so promising, so fruitful, so unfortunately interrupted, should be revived and continued. In our endeavors to advance that great work against ignorance, indolence and prejudice in quarters high and low, we shall surely miss henceforward his voice and pen.

In 1879 he accepted an appointment to lecture at the School of Mines, Columbia College, on "The Manufacture of Iron and Steel." He wrote these lectures with great care, printed a complete synopsis of them for the use of the students, and took as much pains to assure himself of the proficiency of his class, by rigorous examinations, as if he had been a resident professor, and this his chief business.

Besides the two early patents which I have already mentioned, Mr. Holley obtained fourteen others. Ten of these refer to his improvements in the Bessemer process and plant; two of them to roll-trains and their feed-tables; and the remaining two are those of July 8, 1876, and March 1, 1881, the first for a water-

* This catalogue will be published in the "Memorial Volume."

cooled furnace roof, and the latter for a steam-boiler furnace, with gaseous fuel. These are both important; and the first of them, in which the pipes cooling the arch of a furnace constitute at the same time the skeleton supporting it, is highly ingenious in conception and detail. It is not unlikely to be the "furnace of the future" for many purposes. The last of his Bessemer patents (purchased since his death by the Bessemer Association), that of the detachable converter-shell (April 26, 1881), is perhaps the most important of all, after the old converter-bottom patented August 9, 1870. I will not describe it here. It is discussed by its inventor in a manner to leave nothing more to be said, in a paper read in November, 1880, before the American Society of Mechanical Engineers.

It is pleasant to remember that in these later years he began to receive the public and professional recognition which his genius and perseverance deserved. In 1878, on the twenty-fifth anniversary of his graduation, his Alma Mater bestowed on him the honorary degree of Doctor of Laws. A still more appropriate honor, the Bessemer medal, given in cordial though late appreciation of his services and merits, can be placed, not alas! in his hand, but only on his tomb. But these things are but trivial symbols of the warm, unanimous, universal love and respect with which he was regarded by the engineers of two worlds.

This has been more adequately shown by the outburst of sorrow and of eulogy on both sides of the Atlantic, which followed his death. Yet scarcely less significant was the cordial welcome which, while he yet lived and labored, awaited him everywhere on his journey. All doors—even those which were inscribed with "No admittance"—opened before him. One of his friends who has been traveling this year among foreign iron and steel works, writes that Holley's name has been everywhere a potent charm, securing for him an eager courtesy of reception.

I have resolved to make this address, as far as may be, purely professional and critical; and there has been no lack of testimony to Holley's private virtues and personal magnetism, so that I need not dwell at length upon these. But even in a cold estimate of his professional achievements, these qualities cannot be passed over. Generosity, honor, tact, unselfish interest in the welfare of others, high devotion to great causes, unstinted service to the interest of employers, a full performance—nay, an overflowing performance—of every duty; these qualities win love and trust;

and to win love and trust, in our profession, as in every other, is the very heart of success.

We may answer now the questions with which we began. This life *was* successful. It was filled with the joy of labor; it was surrounded at the last with comfort and fame and troops of friends. But the success was not of accident, or luck, or sudden growth. It was earned, inch by inch; won out of innumerable delays and defeats; held at the cost of constant vigilance and toil. Homer sings of warriors who were invulnerable and irresistible; but Homer gives them the assistance of the gods, fighting invisibly beside them; and to my mind, his noblest heroes are those who stand up bravely against such odds, and die where they stand. Again, the tales of chivalry are full of triumphant champions, whose lances in *melée* or tourney nothing can resist. But history tells us that, apart from the exaggerations of the legend, these all-conquering heroes were arrant humbugs—princes, whose prowess it was the part of courtiers to help them to exhibit; that their invariable triumph was the farce of hired players. *Our* hero was no such gay cavalier. Neither miracle nor connivance made his lance omnipotent. His armor was bruised and dented in earnest; he knew the shock, the overthrow, the retreat, the struggle again and again renewed, the victory that called for new conflicts with new risk of defeat.

If Holley's genius was such as to forbid us from hoping by mere effort to attain equal heights, yet, on the other hand, there is ample encouragement and instruction in his career for all young engineers. Let me, in closing, barely mention its chief lessons.

The first is the great benefit of uniting theory and practice. It is less important how these are to be combined than that the student of either should not despise the other. Every word that Holley spoke, every line he wrote, betrayed his familiarity with the practical operations, tools, difficulties, and needs of his business. A great inventor once said to me (when I talked to him of some fancied discovery of my own): "My boy, half the art of invention consists in knowing what needs to be invented." Holley's career illustrates this principle, and bears witness, also, how deeply he felt what he called the inadequate union of engineering science and art, and how ardently he labored to make it closer and more complete. Not his eloquent words merely, but the eloquence of his whole life speaks one language—the language of the brotherhood of brain-workers and hand-workers. And what he was, even more

than what he said or did to promote such union, wrought mightily to that great end. For the end is to be found in the multiplication of such men as he—men who do not merely preach harmony to the two classes, but actually belong to both.

It is important to observe that the foundation of his training was wholly American. Far be it from me to disparage the advantages of foreign study. I would not speak such treason to my own Alma Mater in a far land. But I say without hesitation, that he brings most from travel and study abroad who carries most to them. Many a precious graft they have furnished, and will yet furnish, to our native stock; but the stock is as important as the shoot, and there are too many young men returning with their hands full of scions and nothing to graft them on. How illustriously different was Holley's career!

Another important matter is the early cultivation of the observing powers, and, as incidental thereto, the art of drawing. Holley's facility in these respects was an inestimable advantage to him. He inclined to graphic methods of stating and solving engineering problems; and his eye, thus trained, became an intuitive judge and calculator.

Then comes, in natural succession, the habit of instant, rapid, accurate, methodical recording of observations. It was Holley's practice to do this constantly; to make every record so clear and complete that it could be comprehended and used after years had passed; and to index his note-books and scrap-books so that they became thoroughly available at any moment. This is no trifling matter. When the officers of our Corps of Engineers are examined as to their fitness for promotion, they are obliged not only to answer questions and prepare "projects," but also to exhibit the note-books they have kept during their terms of service. No other revelation of character is more significant, no test more severe. The work that a man does in a hurry, and unobserved, and for himself, not the public, tells the story of his method and temperament. Holley's note-books are models of fullness and order.

But neither observing, nor recording, nor studying, nor the combination of all these with practical training, completely furnish the engineer for the highest place. For he has to deal, not merely with matter and mathematics, but also with men. They must be made to recognize his skill, to back his enterprise, to coöperate in his achievements. Influence, *influence*—that is the secret of power.

Genius may seize opportunities; influence brings them. And the chief vehicle of influence is language. The mastery of language, therefore, is no superfluous accomplishment to the engineer. The young man who deliberately and of choice says, "I mean to be scientific, but not 'literary;'" or the parent who says, "My boy is not going to need a liberal culture; he is going to be an engineer," is ignorant of the most potent principle of modern life—the solidarity of the race, the dependence of each upon all, the necessity of a wide foundation for a high fame, the universal law that every occupation deals ultimately with men even more than with things, and that the ability to shape things is almost barren without the power to move men.

But language, as the means of this power, is effective in proportion as it is filled with appeals to the responsive associations of human minds. A host of things in fancy, poetry, history, and general literature, concerning which people are interested, may be trivial in themselves; it is nevertheless worth while to know them and to use them, as a means of commanding the interest and assent of men. In other words, a wide culture, in sympathy with the age in which we live, is an element of power. It is true that all this, belonging to the art of expression, is wasted in the hands of him who has nothing to express. Men may be arrested to listen, but they will soon find out that behind the skillful utterance there is neither character nor knowledge. They may be fascinated by the instrument, until they find out there is nothing in the tune. But when real genius and noble ambition utter themselves through the channels of art in language, how gladly hears the world!

Holley's versatility and intellectual sympathy with many lines of thought prevented him from sinking to the level of drudgery, though he worked harder than many a drudge; they made him not merely a bricklayer, but an architect for his generation. Controlled and reinforced by a mighty perseverance, softened and brightened by an unfailing gentleness of soul, they added to his genius that which made him great. For what we call greatness in any sphere is simply *recognized excellence*. The excellence may be spurious, the recognition may be factitious and ephemeral—then the greatness is false, and the great of to-day are forgotten to-morrow. But when a noble character has been nobly exhibited, when genuine power has won genuine praise, when fame soars not for a brief flight into the windy air, but stands firm-footed on the solid pyramid of achievement, to sound through her silver trump

the name of her victorious son—conqueror of nature, leader of men—this greatness will endure.

Build him a monument that shall testify our love and his renown. Let the world understand that not alone the plots of politics or the luck of war may give title to such public memorials. This witness, addressing as it does the imagination, the ambition, the worthy pride of the greatest number of men, is conspicuously appropriate to a life so many-sided and complete, so simple and sincere, yet so popular and influential.

He did not, as once he feared he might, go down poor and unknown, carrying with him thoughts of which the world was not worthy. He was heard, believed, accepted, rewarded—with no greater delay or difficulty than sufficed to bring out to their full extent his own best powers. It was given to him to do grand things in the sight of all men. And beneath all our words and pictures and statues of him lies forever a sure foundation—the work that he did for his time.

Foresters tell us that a tree once marked will retain the mark, though a hundred years of growth may have overlaid it with later coverings. What may be the future spread and stature of the stately oak of American engineering we cannot presume to foretell. But there will come no time when the historian, stripping off the rugged bark, and cutting through the rings of many generations, will not find at the heart that name which with keen blade and skillful hand was carved by Alexander Lyman Holley!

THE MECHANICAL ENGINEER—HIS WORK AND HIS POLICY.

THE PRESIDENT'S ANNUAL ADDRESS.

BY

ROBERT H. THURSTON, HOBOKEN, N. J.

GENTLEMEN OF THE SOCIETY:—LADIES AND GENTLEMEN:

It is with mingled feelings of pleasure and of regret that I appear before you, for the third time, to deliver the formal opening address at the annual meeting of the American Society of Mechanical Engineers.

I have to express, inadequately as I may, my sense of the honor accorded me and my appreciation of that kind feeling and of that confidence which placed me in this chair as your first President, and to-day particularly, my gratification that, after conferring that distinction for another term, both officers and members have so kindly and effectively upheld me in the effort to secure a firm and permanent basis for future usefulness for this Society.

In retiring after two and a half years of service, I have the proud satisfaction of being able to look back upon an initial period in the history of the Society which is, perhaps, unexampled, and I gladly fall back into the ranks of a body which already numbers 350 members, and which includes in its list nearly every distinguished engineer in the country as well as a large number of the younger and brighter minds now coming forward to do our work—a Society which boasts on its list of honorary members the greatest engineers of Europe.

In the first of my two earlier addresses I attempted to lay before my audience a concise statement of the character of this organization, the objects proposed to be attained in its formation and by its action, and the principles which I conceived should guide it, as a body, as well as its members individually, in their efforts to further those objects.

In my second annual address I endeavored to indicate what progress had been made, and what stage had been reached, in the various arts which constitute our department, and to show what direction our steps are now taking and what are the needs of the time so far as they concern the mechanical engineer. I pointed out

what seemed to me the more important problems presenting themselves for solution, and stated what were apparently the most promising directions in which to seek results.

I finally called attention to the relation of technical instruction, and of systematic training in the arts to our profession, and urged the supreme importance of making, promptly, the most energetic efforts to inaugurate a general and complete scheme of public and private education.

In this, my third address, I propose to review very briefly the work of the mechanical engineer up to this date, to present a concise summary of what has been accomplished, and to again examine the line of progress with a view to ascertaining more exactly than before in what direction our labors may be most profitably directed in the near future. Nature rarely turns a sharp corner in any of her great movements, and the direction of our progress may be expected, in the immediate future, to be very nearly what it has been in the recent past. Newton's laws hold as well in sociology as in mechanics.

Finally, I propose to touch upon those great social problems which concern the engineer even more than our fellow-citizens, not simply because he has to deal more directly with them, as an employer and a director of labor and of capital, but, principally, because it is his province, his duty, his privilege, more than that of other men, to study and to solve them, and to inaugurate and carry to completion all those great measures to which their solution leads.

MATERIALS.

In the handling of metal, we have still much to learn. The weakness of the large sections of metal necessarily used in our heavier work still remains a serious evil, and our inability, especially when using steel, to secure the highest tenacity of the metal is a standing reproach to our profession. I have had occasion to test hundreds, yes, thousands, of samples of iron and steel during the last few years, and have never yet found a maker able to give equal tenacity in large and small sizes. The difficulty seems particularly serious in dealing with forged iron built up of scrap and with heavy sections of any kind of steel. I find iron carrying 75,000 pounds per square inch in No. 8 wire, 55,000 in inch bars, and falling to 40,000, or even 35,000, in heavy engine-shafts and beam-straps. Steel varies still more seriously. It is to be hoped

that, with the more general use of ingot metal, the introduction of hydraulic forging and of improved methods of heating and handling, so as to avoid the introduction of many small parts in building up large masses, or frequent exposure to high temperatures in the process, this element of cost and danger may, in a measure at least, disappear.

The great testing machine at Watertown Arsenal is constantly at work, under the direction of Colonel Laidley, sometimes for private and sometimes for public benefit, and has already done some extremely valuable work in that important and unexplored field—the investigation of the strength of large sections and parts of structures. Its most valuable work is done intermittently and its usefulness is far less than it should be, and would have been had its original purpose been adhered to. There seems no immediate prospect of the resumption of the great work organized in 1875, and planned and commenced by the Government Board.

The petitions of this Society, of the Society of Civil Engineers, of the Institute of Mining Engineers, of the Iron and Steel Association, of the faculties of the leading technical schools and colleges of the United States, and of business men and other private individuals of all classes, with all the influence that they could command, separately or collectively, have been inadequate to secure the restoration of that Board, or the creation of a similar organization, or the resumption of the great work barely planned and begun by the old Board.

This fact is as suggestive of the necessity of a movement on the part of the business men of the country for the purpose of securing some influence in its government, as it is remarkable as illustrating their utter impotence to-day. Meantime, the Ordnance Bureau of the Army has a small appropriation for use in this direction and we shall look with hopeful interest for results.

But "Iron, tough and true, the weapon, the tool and the engine of all civilization," as Theodore Winthrop calls it, is now fairly displaced by its younger rival, "*mild steel*," or, more exactly, "ingot" or "homogeneous" iron.

For all shapes that can be rolled, this revolution is accomplished; and, in forged work of small size, the change is hardly less complete. This is especially true of railroad work, and not only rails, tires and axles, bolts, rivets and boiler plate are becoming common in steel, but piston and connecting rods, all forged parts of the valve gear and minor parts of the engine, are now made in this tougher, stronger, and more uniform and reliable metal.

The introduction of the basic process—tardy as it is—by cheapening the stock of the steel maker, and the steadily increasing familiarity of makers and users with the characteristics of the new metal, and with the requisites for successful manufacture of demanded grades and better qualities, will undoubtedly, before many years, make its use so general that puddled and forged iron will become almost or quite unknown in our art. The growth of pneumatic steel manufacture in this country during the past ten years has been most remarkable. In 1870 we were making somewhere about 20,000 tons, in 1873 about 160,000 tons, and to-day are turning out 1,750,000 tons; while the price has fallen below that of the finer brands of iron.

A few years ago—even those among us whose hair has hardly begun to turn gray can remember the time—no engineer except Telford, with his proposed cast-iron bridge of 600 feet span, had dared present plans of iron truss or arched bridges of 300 feet span; and Roebling was the only engineer bold enough to attempt much greater spans, even with suspension bridges.

To-day, with improved material and the better knowledge of their quality that comes of intelligent inspection and systematic test, we think little of trusses of 500 feet span, or suspension bridges of 1,000 feet and more; and it is even proposed to bridge the Forth at its expansion into the Frith with a steel truss bridge a mile long, containing two main spans of 1,700 feet each. Not the least remarkable and—to those who pay taxes in New York or Brooklyn to defray the cost of the "East River" bridge—interesting fact in connection with this scheme is that it is expected to cost but about $7,500,000. Who shall say that we are not making progress in this direction at least?

The reduction in cost of the purer, stronger, tougher and more homogeneous grades of so-called "steel" which are to take the place of iron in the near future, and of those which are made by the "open hearth process," especially, will depend principally upon the introduction of the regenerative type of furnace, the great invention of that greatest of metallurgical engineers, our colleague, Siemens, and of the lesser inventors who have followed his lead. With this furnace supplying a means of attaining any desired temperature with a pure mild flame and at a wonderfully low cost of production, we are able to produce the boiler steels and similar metals with an economy that permits competition in this field with even the product of the Bessemer process. With the closed furnace, the

attainable temperature is only limited by the temperature of fusion of the materials of the furnace. Could a new and sufficiently refractory furnace material be found, it might possibly be able to compete with the electric arc with which our colleague Farmer, that Nestor among our electricians, claims long ago to have produced the diamond. The melting of platinum in considerable quantities by Ricketts is now a familiar fact, and is an earnest of what may be expected in the more ordinary departments of metallurgy when such enormous temperatures shall be found manageable.

We are not yet absolutely free from annoyance by the presence of air-cells and minor defects in these "ingot-irons," as they are properly called; although such defects have ceased to be dangerous or in any way very serious. Captain Jones' method of compressing the solidifying ingot by steam pressure, and other devices in imitation of his, are giving us a very homogeneous metal.

Singularly enough, our people, enterprising as we are accustomed to consider ourselves, have not yet made use of the Whitworth system of compression of steel, notwithstanding the fact that its value has been known so many years, and though the wonderful strength, uniformity and toughness conferred by it have made "Whitworth compressed steel" famous throughout the world. Abroad, its use is extending, and guns, screw shafts and other heavy "uses" are often made of it. The venerable inventor informs me that he is preparing plans that will enable even large castings of peculiar shapes, as screw propellers, to be made of this material. Some dozen years ago, studying this method and its results, partly for my own satisfaction and partly to obtain material for a report to the Navy Department, I was greatly impressed with its efficiency as even then developed, and its work has since been wonderfully extended and its value correspondingly increased.

Our systems of inspection and tests of materials, of parts and of structures are steadily assuming satisfactory shape, and are becoming very generally, almost universally, adopted in all important work, whether public or private, and it will soon be the exception rather than the rule that supplies, material, or constructions of whatever kind, are purchased without a careful determination of their fitness for their intended purpose.

METHODS.

In my last address, I referred very briefly to the modern *Method of Manufacturing Machinery* in quantity for the market as dis-

tinguished from the old system, or lack of system, of making machines. This method compels the adaptation of special tools to the making of special parts of the machines and the appropriation of a certain portion of the establishment to the production of each of these pieces, while the assembling of the parts to make the complete machine takes place in a place set apart for that purpose. But this plan makes it necessary that every individual piece of any one kind shall fit every individual piece of another kind without expenditure of time and labor in adapting each to the other.

This requirement, in turn, makes it necessary that every piece, and every face and angle, and every hole and every pin in every piece, shall be made precisely of this standard size, without comparison with the part with which it is to be paired, and this last condition compels the construction of gauges giving the exact size to which the workman or the machine must bring each dimension.

Finally: In order that this same system which has introduced such wonderful economy into the gun manufacture, into sewing-machine construction, and into so many other branches of mechanical business, may become more general, and in order to secure that very important result, a universal standard for gauges and for general measurement, we need an acknowledged standard for our whole country—one that shall be an exact representation of the legal standard measure, and one which shall be known and acknowledged as such, and as exactly such.

It could hardly be expected that private enterprise would assume the expense and take the risk involved in this last work. Such work has heretofore only been done by governments. Yet among our colleagues are found the men who have had the intelligence, the courage and the determination to accept such risks and to meet such expense, and the men who have the knowledge and the skill needed in doing this great work. I think that the report of our committee on gauges and the paper of our colleague, Mr. Bond, will show that this great task has been accomplished, and we shall find that we are indebted to the Pratt & Whitney Co., to Prof. Rogers and to Mr. Bond for a system of measurement and a foundation system of gauges that will supply our tool makers and other builders with a thoroughly satisfactory basis for exact measurement and for accurate gauging.

It is encouraging to observe that this subject is attracting the attention of men of science, and that so distinguished a body as

the British Association for the Advancement of Science is taking action regarding it.

DESIGN.

Design is to-day conducted systematically and with scientific adaptation of means to ends. The day of the *soi-disant* inventor by profession has gone by, and the educated and trained designer has usurped his place. Reuleaux's kinematic synthesis determines the form to be taken by the machine when once the object sought in its construction is plainly defined, and an intelligent application of the laws and data of strength of materials gives its parts their safest and most economical forms and proportions.

The process of invention thus becomes a scientific one, and the inventor himself, instead of blindly groping for or guessing at results, is seen intelligently creating new and useful forms, and is now entitled to claim the higher credit and the nobler distinction that we gladly accord to him who performs so high an order of intellectual work, and to none more cheerfully than to him who applies the grand Science of Engineering to the production of new forms of mechanism.

As in the Fine Arts the great painter is known by his success in composition and in form rather than in color, so in our own art the best work is that which is distinguished by excellence of general design, of arrangement of detail and of proportion, while aimless ornamentation has no place. This characteristic of true art will become more fully illustrated as the scientific method of invention and design gains ground. The most direct and simple adaptation of means to ends will always be the object sought by the engineer; and the labors of one of our honorary members, Dr. Reuleaux, have led to the development of a scientific method of discovering those means.

HYDRAULICS.

Let us now look in another direction.

The mechanical engineer has open to him as his exclusive province one department which is, as yet, only partially developed in practice, although well advanced in theory. I refer to that of *Hydromechanics*, and especially the utilization of water power. Although one of the earliest opened by the old Greek engineers, it has been one of the latest developed. Archimedes, Ctesibius and Hero were familiar with the principles of fluid pressure; Torricelli, Pascal, Newton and Bernouilli developed the fundamental principles of

hydro-dynamics; Du Buat, D'Aubuisson, Prony, Eytelwin and, above all others, Darcy, supplied experimental data, but it has been reserved for our own generation to apply the knowledge so early acquired to the production of efficient hydraulic engines.

But a few years ago, the vertical water-wheel, as constructed by Fairbairn for moderate and for high falls, and the undershot wheel of Poncelet were the standard wheels in all countries, notwithstanding their cumbrous size, their slow movement and the great cost involved both in their own construction and in that of their machinery of transmission. Their efficiency was thought high, although rarely exceeding 75 per cent. These wheels have had their day, and nothing is likely to occur to save the whole class from ultimate disuse.

The turbine, introduced in an effective form by Fourneyon, a half century ago, and especially in the later forms of Fontaine, Henschel, Jonval, Schiele and others abroad, and by Boyden and his successors in the United States, has become the only water-motor in general use. This small, cheap, quick-running wheel has completely displaced all the older forms, whether overshot, undershot, or breast wheels.

The three principal types—parallel, inward flow and outward flow—are all in use and doing good work.

In Europe, they are all made by good builders, as here; but the tendency seems to be, in the United States at least, to introduce most generally another and peculiarly American type—the inward and downward flow wheel, as illustrated in the wheel built by our fellow-member, Risdon.

In efficiency, notwithstanding the comparative neglect of these motors by scientific investigators, there has been a steady and important gain during late years. The improvements which have been *felt out* by makers, working often in the dark—for few builders claim to understand the principles of their art, and no two, even, ever agree in their statements of the principles underlying their practice—have resulted in a gradual elevation of standard, until to-day a wheel which, under favorable circumstances, cannot exhibit an efficiency of 80 per cent. must drop into the background. I have been asked to certify a trial giving, as claimed, 95 per cent.; but that figure could, I am sure, only be attained by chance, if at all, when all conditions conspired in its favor. But wheels are, I have no doubt, doing work by the day and by the week at 80 per cent. It may be said that Boyden did as well a

generation ago. True, but only with large wheels, built as carefully as the chronometer is made, and fitted with polished buckets and diffusers, and tested under conditions purposely made the best possible. To-day our builders of turbines give their wheels such exact proportions and take such care in the ordinary work of the foundry that they obtain these high figures from wheels almost direct from the sand.

So far has this change gone that our theory of the turbine as modified by friction requires careful revision. Accepting the older co-efficients for friction and losses of energy, it will probably sometimes be made to appear, from experimental trials, that the wheels of our best makers are a trifle better than perfect. It would seem from figures sent me that friction, in a well-formed wheel, becomes partly a means of transfer of energy from water to wheel, and that the loss of efficiency due to that element is much less than has been supposed. In some of the later wheels, losses of energy due to eddies occurring within the flowing mass have been reduced to such an extent as to considerably improve their performance. In the regulation of the turbine, an excellence has been attained that is thoroughly satisfactory in some cases, and the best wheels have been found to give an efficiency at half and at three-quarters gate nearly equal to the best at full gate. As the efficiency at part gate is often more important than at full gate, it is easily seen that this means a vitally important gain.

MILLING.

A feature of recent progress of general interest, not only to engineers, but to every citizen, is the recent change in *Methods of Milling*.

It has been found that the cutting action of the millstone is not best adapted to the preparation of a good flour; but that the crushing action of the mortar and pestle or of rolls is much more efficient.

"Roller mills" have been long in use in Europe, and the Hungarian flour, so long noted as the finest in the world, owes its excellence, not simply to the gluten-charged wheat from which it is made, but largely to the systems of "high-milling" and of cylinder-milling, by which its fine grades are produced. The system of "high-milling" is a process of gradual crushing and grinding by a succession of operations, each of which gives a finer product than the preceding, while the intervals between them permit the grain to lose the slight heat produced by the slow-running stone. The

first step removes the silica coating, and the grain is next cracked, then broken up, and finally reduced to fine flour without loss of gluten or other injury, and with less waste than by the familiar system of "low-milling."

By the latest and best method, the grain is gradually reduced to fine flour by passing through a succession of pairs of rolls. In the great "*Walzen-Muhle*" at Pesth, from eighteen to twenty-four pairs are used in making the fine grades of flour. It is this method that is coming into use in our own country, and our hard North-western wheats are made by it into a fine, nutritious flour, rich in gluten, with its grain-cells intact, readily converted into the finest of bread, and capable of making 150 to 170 pounds of loaf per 100 pounds of flour. The great "Roller-Mill" at St. Paul, Minn., has a capacity of production of 500 barrels per day, and the hard wheat of the North-West supplies it with unexcelled grain.

TRANSPORTATION.

The modern system of collecting the grain raised in all parts of our country, from the Atlantic to the Pacific, from the Southern States to the great grain-raising districts of Dakota and Manitoba; the system of storage of the annual product, which now includes 1,600,000,000 bushels of Indian corn and nearly 700,000,000 bushels of wheat, in the great elevators of Chicago, Buffalo, New York and Boston; these latter methods of milling; our organization of a meat supply, taking herds of cattle from Texas for the markets of the North and East and for transportation to Europe; our system of packing meats at St. Louis, Cincinnati and Chicago, its carriage in refrigerator cars to the seaboard and in marine refrigerators to European ports; our methods of canning meats as well as vegetables, and thus preserving them from season to season; all these now familiar ways of reducing the cost of living are making further advancement toward a higher civilization easier and more rapid. They supply the first of the two essentials to healthful progress—cheap food and other necessarily consumed necessaries of life—and industrious habits of skilled labor are then to be relied upon in the production of the permanent forms of wealth.

Our systems of transportation are peculiarly the work of the engineer, and are the especial objects of his care. Planned by great engineers like John Stevens, John B. Jarvis, and others, of whom we boast as statesmen as well as engineers; built under the direction of Roberts, Welch, McAlpine, and other great constructors,

they remain in the hands of successors skilled in management and maintenance. All the enormous accumulation of capital in the form of rolling stock is the product of mechanical engineering, and the thousands of trains daily speeding across the land, each representing in value $30,000 to $150,000 and carrying hundreds of human beings, or property worth from $20,000 to $500,000, depend for their safety upon the thoroughness of the builders' work, and upon the coolness, skill and judgment of the man who handles throttle, brake and reversing lever—an obvious and forcible reminder of the importance of a profession, one of the humblest and least considered member of which is laden with such enormous responsibility.

ELECTRICITY.

Turning now to the work of the last-established branch of our profession, *Electrical Engineering*, we find ourselves still in the midst of a revolution, the progress of which we are all watching with unusual interest—the displacement of our older methods of supplying light and power by a new system, which but lately was but the toy of science, and which comes out of the least utilitarian of all the branches of pure physics. Brush has set up his blazing, sun-like, arc-lights in nearly every large city in the world; Edison has spread a net-work of conductors throughout the most densely settled part of New York City, distributing many thousands of his clear mellow lights to send their soft, white rays into corners never yet revealed by the feebler yellow light which they displace. It remains to be learned what is to be the cost of the new method of illumination; no figures that I consider wholly reliable have yet been given. It seems sufficiently certain, however, that the arc light is much more economical than gas—the same quantity of light being demanded—for the illumination of streets, public squares and large interiors, while interior illumination by the incandescent lamps is still generally more costly than any other usual method.

The danger to life and property which come in with the new light are becoming rapidly less, as safe methods of laying and connecting the "mains," of handling the plant and especially more careful and skillful inspection become generally known and practiced. They still remain so great as somewhat to retard the introduction of the electric light.

The secondary batteries of Faure, Planté, and others are likely to aid, after a time, in bringing the light into use in many localities

in which it would otherwise be impossible to adopt it with satisfactory results and in cheapening the cost of supply. They are still too cumbersome to be of as great value for general purposes as was hoped when they were first invented.

Despite every difficulty and every objection, however, the electric light is steadily and surely coming into a very wide field of application. Its beautiful whiteness, its brilliancy and clearness, its richness in the actinic rays, and therefore its power of revealing every shade of every color, and of producing the chemical changes of photography, its freedom from heat, from vapor and from gaseous poisonous products of combustion, and even its curiously interesting effect in promoting the growth of plants, must all prove qualities of such importance that its extensive introduction, although hardly its exclusive use, must be soon accomplished. As remarked recently by Siemens, gas will long remain the poor man's friend, supplying his rooms with light, and probably his kitchen, ere long, with heat.

Little has yet been done in the electrical transmission of power, except to determine experimentally the efficiency of the system.

I stated last year that the efficiency of the Edison system had been determined, and found to be about 90 per cent. Howell's results have been confirmed by Hopkinson, and by Siemens abroad, and are also checked by reference to Tresca's earlier work. Recently the Messrs. Gibbs have made an extended study and test of the Weston machine; and they also find the earlier reported figures for electrical transmissions more than confirmed. Taking the probable efficiency of the two machines forming the system in electrical transmission at 85 per cent. each, we obtain a net efficiency of the system, exclusive of conductor, of above 70 per cent.—this is precisely Tresca's figure, if I remember aright—and, allowing liberally for losses on the line, we may say that 60 per cent. of the power generated may be utilized. But a good engine of large size should give a horse-power with 2 to 2½ pounds of coal per hour, while the small engines which may be displaced by it will demand from 8 to 12 pounds, thus giving an enormous advantage to a system distributing a large aggregate of power to many small users. We shall all look with great interest to the result of actual trial. The electrical railways at Berlin, in Paris, and in Ireland, and Edison's road at Menlo Park, are not likely to remain long uncopied. Our own elevated railroad system offers the best possible field for the utilization of this system; and the often-proposed

scheme of burning all our fuel at the mine, and transmitting light, heat, and power in our cities along electrical conductors, begins to seem almost a practical one. We may begin to look once more to thermo-electrical generation as a possible method of transformation at the source of power, as proposed by our distinguished colleague, Farmer, years ago. The fact that while a 4-horse power dynamo deposits about 700 pounds of copper in 24 hours, expending, say, 400 pounds of fuel, at least, in usual work, Farmer deposited 400 pounds of copper 20 years ago, nearly, with an expenditure of but 109 pounds of coal burned in his thermo-electric battery, is an important one to be kept in mind in this connection. We may, perhaps, look soon to see this branch of the subject again taken up, and a battery again constructed capable of melting tungsten, and of fusing 8 pounds of platinum in 20 minutes.

Before leaving this subject, it is pleasing to note that in the introduction of new electrical units, our great predecessor, James Watt, is accorded deserved honor, beside Ampère, Weber, Ohm, Coulomb, Volta and Faraday, and that so barbarous a system of nomenclature is made a means of perpetuating the name of so great an engineer, as well as those of such great physicists.

STEAM.

In *Steam-Engine Practice* we are not now advancing rapidly. The introduction of the "drop-cut-off" in 1841, by Sickles; of the now standard type of automatic valve gear in 1849, by Corliss; of the high-speed engine, twelve years later, by Allen and Porter; of the combined advantages of jacketing, superheating and reheating, and the definite acceptance of the compound engine in later years, still constitute the complete history of modern steam engineering; but we are, nevertheless, continually gaining a knowledge of the best methods of handling higher steam; of attaining higher piston speed; of securing greater immunity from cylinder condensation and leakage, and of providing against other causes of waste. We are just beginning to perceive what principles must govern us in the endeavor to secure maximum commercial efficiency, and how economy in that direction is affected by the behavior of steam in the cylinder, and by the mutual relations of all the various expenditures that accompany the use of steam power.

The younger Perkins are still leading in the practice of carrying high steam, and make 400 pounds per square inch—27 atmospheres—as a usual figure while they are experimentally repeating the work

of the elder Perkins, and of Dr. Albans, of forty years ago, working steam at 1,000 pounds or nearly 70 atmospheres.

Unfortunately, the gain to be anticipated by the use of these enormously increased pressures does not seem likely to be very great, unless some decidedly less wasteful kind of engine can be devised in which to work it. The "Anthracite," with steam at 300 pounds and upward, was less economical in fuel than the Leila, carrying about one-third that pressure. Emery has stated that a limit seems to be found at about 100 pounds to economical increase of pressure; and Stevens finds a limit due to the causes producing or modifying the geometrical character of the indicator diagram, inside of 250.

One of the most interesting and curious, as well as important, deductions from the rational theory of engine efficiency is the existence of an "absolute limit to economical expansion,"—lying far within the previously accepted limit—due to the fact of increase of cylinder condensation and waste with increase in the ratio of expansion, which places an early limit to the gain due to expansion *per se*. It seems possible, if not certain, that this point is often actually reached in ordinary engines within the range of customary practice.

All these facts combined point to a probability that we have little to hope for in the direction of increased steam-engine economy with our standard machinery. Change in the directions that I have already so often indicated are evidently to be our sole reliance—changes limiting loss by cylinder condensation. Probably the surrounding of the working fluid by non-transferring surfaces is our only resource, in addition to, or in substitution for, the now well-understood expedients of high piston speed and super-heating. Until that is done, steam jacketing remains a necessary and unsatisfactory method of reducing losses. With a non-conducting cylinder, were it procurable, we might secure very nearly the efficiency of the ideal engine, friction aside, as it would be a "perfect engine," and no natural limit would then exist to increasing economy. Were this accomplished, we might at once reduce the cost of steam power by about one-half in our best engines, and to probably one-fourth or one-fifth the present cost in ordinary machines.

In steam engineering, both physicists and engineers are more than ever attracted to the study of those phenomena which produce the familiar and enormous differences, even in the best practice, between the thermo-dynamic and the actual efficiencies of engines. The subject lies in that "march-land" territory between science and practice, which few of the profession can explore from both sides,

and it has remained less known than it would otherwise be were it either a matter of purely physical science or of practical experience. Fortunately, we are likely soon to see it thoroughly studied. The debate which arose not long since between Zeuner, the distinguished physicist, as a representative of pure science, and Hirn, the no less distinguished engineer, as an experienced practitioner and skillful experimentalist, in which the differences, to which I have so often called attention, of fifty per cent. or more between the "theoretical" efficiency and the actual performance of the best steam engines seem for the first time to have been given prominence in Europe, has led to a much closer study of the matter than could possibly otherwise have been brought about.

On this side the Atlantic, the discussion of steam engineering efficiencies has been carried on earnestly, if not always with that knowledge that should precede criticism, and it is to be hoped and anticipated that the engineer may ere long be put in possession of positive facts and real knowledge that may aid him in so designing and so applying this greatest of modern inventions as to attain the maximum of economy.

Ten years ago, nearly, I took occasion to state in a report to the President of the United States on the exhibited machinery of the Vienna exhibition of 1873, printed later with the other reports of the United States Scientific Commission, that, "The changes of design recently observed in marine engines, and less strikingly in stationary steam engines, have been compelled by purely mechanical and practical considerations. The increase noted in economy of expenditure of steam and fuel is, as has been stated, due to increased steam-pressure, greater expansion, and higher piston-speeds, with improved methods of construction and finer workmanship. These several directions of change occur simultaneously, and are all requisite. To secure maximum economy for any given steam-pressure, it is necessary to adopt a certain degree of expansion which gives maximum economy for that pressure under the existing conditions.

"This point of cut-off for maximum efficiency lies nearer the beginning of the stroke as steam-pressure rises. For low pressure a much greater expansion is allowable in condensing than in non-condensing engines; but, as pressure rises, this difference gradually lessens. For example, with steam at 25 pounds by gauge, the best economical results are obtained when expanding about three times in good condensing engines and about one and a half times in non-condensing engines. With steam at 50 pounds, these figures be-

come five and two and a half, respectively; and at 75 pounds, the highest efficiency is secured in condensing engines, cutting off at one-fifth, and in non-condensing engines, with cut-off at one-third stroke.

"Owing to the decreasing proportional losses due to back-pressure and to retarding influences, the departure from the economical result indicated for the perfect engine becomes greater and greater, until, at a pressure between 200 and 250 pounds, the proper point of cut-off becomes about one-sixth or one-seventh, and very nearly the same for both classes of engines, and the increase of efficiency by increase of pressure and greater expansion becomes so slight as to indicate that it is very doubtful whether progress in the direction of higher pressure will be carried beyond this limit."

These conclusions were derived from careful observation of the performance of unjacketed "single cylinder" engines and a comparison of the ratios of expansion of those exhibiting greatest economy. It is interesting to note that later, and probably more reliable methods of comparison than were then familiar go far in confirmation of the opinion then expressed. I think that I have been able to prove the existence, as just stated, of an "absolute limit of economical expansion," which, whatever the ratio of steam pressure to back pressure, in all known heat engines probably falls within the range of familiar practice. Advance beyond the best efficiency of to-day in ordinary engines seems likely to be very slow and not at all likely ever to be very great.

Extended experiments will be needed to secure all the facts demanded by the designing engineer, and to furnish constants for the approximate theory of efficiency, which is only, as yet, his sole guide. An exact theory is one of those things for which he hopes but which he does not expect soon to see. Some experiments have already been made, but they contribute only the first step. Those made by order of the Navy Department, and principally by Isherwood, and those of Hirn have hitherto been our sole guide, but a new line of more direct investigation of the laws governing internal, or cylinder, condensation has been inaugurated by Escher, of Zurich, and we are able to see a fair prospect of obtaining definite information in this direction.

Escher finds, in the case taken by him, that this waste varies nearly as the square root of the period of revolution and of the pressure, and is nearly independent of the back pressure—conclusions which are especially interesting to me as corroborating assumptions, based

on general observation and non-experimental practice, made by me previously in developing an empirical system of design.

In steam-boiler engineering, the only observable change seems to be the slow but steady gain made in the introduction of water-tube coil boilers and sectional boilers, and in the extension of a rational system of inspection and test while in operation. To-day, the intelligent owner of boilers secures inspection and test, with insurance, by intelligent engineers and responsible underwriters, as invariably as he obtains inspection and insurance of his buildings. Under this system, steam-boiler design, construction and management is becoming a distinct art, based upon real knowledge. The system of forced circulation proposed by Trowbridge, and perhaps others, seems to me likely to prove useful in the solution of the problem to-day presented.

MARINE ENGINEERING.

In *Naval Architecture and Marine Engineering*, the fruits of the labors of our colleagues are seen in the constantly growing magnitude of our steamships, and in the steadily increasing celerity and safety which mark their unceasing transit from continent to continent.

The "Alaska" makes trip after trip, as regularly as a ferry boat, in all but the most trying weather, from Sandy Hook to Queenstown in a week, and has made 18 knots an hour for 24 hours together, and the "Arizona" and the "Servia" are closely rivaling this wonderful performance.

A half dozen years ago I was consulted by an enterprising steamship proprietor who desired to learn how far the substitution of steel for iron would aid in the attainment of his aim—the construction of a line of steamers to make 25 miles an hour from shore to shore. A similar project has been lately discussed, and it would not be surprising to the well-informed engineer if the plan is carried out within this decade.

Even the ill-famed line between Dover and Calais and other channel routes are benefiting at last by the achievements of the mechanical engineer, and the "Invicta," a steamer considerably smaller than the "Pilgrim," has crossed the channel in fair weather in a little over one hour running time—a speed of 18 knots, or 21 miles, an hour—and the "twin" steamer "Calais-Douvres" makes the passage in an hour and a half so steadily that the trying scene

so unpleasantly remembered by every unfortunate who has crossed on the old boats, no longer occur.

The most attractive and difficult of problems presented to the engineer—*to secure a maximum speed, combined with good cabin accommodations and paying cargo capacity*—demands an extent of knowledge and experience, an ingenuity, and a degree of practical skill which are demanded by no other task set before the engineer.

My attention has been called to this subject more strongly than ever before by experiences arising recently in my own practice, and I have been interested in observing how largely the problem resolves itself into one of boiler concentration. The engineering of the machinery is a minor matter; to get a maximum of steam production from a minimum space and weight in the boiler-room and coal-bunker compartment, is a vitally important matter. Even when the cargo space is surrendered, it is difficult to secure speed and good cabins in small steamers, and the scheming of a high-speed yacht of ample accommodations and of good sea-going qualities is a most perplexing piece of work.

Not the least remarkable work in this department has been done, however, on very small craft. Torpedo-boats require but little weight-carrying displacement, and can be loaded with machinery, and thus the disadvantage of their small size is, partly at least, compensated. They have been given astonishing speeds, but only by forcing boilers tremendously to drive the lightest of engines in the lightest possible hulls, over, rather than through, the water.

The art of getting high speed is extremely simple in principles but very difficult in practice. It embraces a very few essential requirements:—(1) Lightness of hull; (2) Excellence of form; (3) Minimum weights carried, whether in cargo, accommodations, fuel, or machinery; (4) Great impelling power, *i. e.*, for best work, a steel hull; small cargo; few stores; fuel for the least time permitted by ordinary prudence; contracted cabins; small engines driven at the highest attainable speed of piston and by maximum safe steam-pressure, and finally, and perhaps principally, boilers of small size, carrying high steam, with minimum water space and forced to the very limit of their power. The art of getting large grate area into a contracted and peculiarly shaped cross-section of hull is one still to be learned.

The torpedo-boats of Thorneycroft and Yarrow in England, and of Herreshoff in the United States, illustrate the most successful practice of to-day, and their attainment of speeds exceeding twenty

miles an hour may be accepted as the most remarkable triumphs of recent mechanical engineering.

With light hulls, weighing but about one-third their displacement, having such fine lines as to occupy but six-tenths the circumscribing cylinder, burning 100 to 150 pounds of fuel on the square foot of grate, carrying 120 pounds of steam, their little engines making 800 to 900 feet of piston speed per minute, at from 500 to 700 revolutions, and weighing but 50 or 60 pounds to the horse-power, this kind of work is locomotive practice of the most radical sort. The secret of success here lies largely in ability to drive the boilers, which are of the locomotive type, forced by powerful fan "blowers," and give a horse-power to each $1\frac{1}{2}$ or 2 square feet of heating surface, and from 20 to 30 horse-power to the square foot of grate.

Now that we are using surface condensation exclusively, there is comparatively little difficulty in the introduction of locomotive practice at sea.

But remarkable and important as is this phase of steam engineering, these little craft have revealed in their performance facts of equal importance in another department. The speeds attained are high, even for large ocean steamers; they are enormously high for such small vessels. It is found that, passing the speeds of 10 or 12 knots, which correspond to high speeds in larger craft, the rate of variation of resistance passes a maximum, and then falls from variation as the cube of the speed, or higher, to the $\frac{3}{2}$ power, and becomes, finally, directly proportional to the speed at their highest velocity, thus giving a comparatively economical performance.

Should the same change of law occur with large steamers, maximum railroad speeds at sea may yet prove to be attainable, when—as I have no question will, ere many years, be the case—we shall burn at sea a hundred and fifty pounds on the square foot of grate in locomotive or sectional boilers, with steam at 200 or 300 pounds pressure, driving engines at 1,000 or 1,500 feet piston-speed per minute, turning screws fitted with guide blades as already practiced abroad, and with machinery of steel in steel hulls of less proportional weight than these torpedo-boats.

It is by such changes as these that the mechanical engineer and his colleagues in the trades are gradually revolutionizing the art of war. Before many years, we hope, war will be made so destructive that no nation will dare venture into a naval contest, and the en-

gineer will have then entitled himself to the glorious distinction of being victor over victory itself. He may thus bring about the death of all war, and may give new meaning to Schiller's song:

> "Honor 's won by gun and saber;
> Honor 's justly due to kings;
> But the dignity of labor
> Still the greatest honor brings."

The screw has become the only instrument of propulsion where it can be used, and I can see no reason to suppose that it will not so remain indefinitely; but engineers, who have hitherto been blindly groping to find some new and peculiar form which may possess mysterious principles of efficiency, have now become fully cognizant of the analogy between the screw propeller and the turbine, and are seeking to apply the well-developed theory of the latter to the former.

The value of a system of guide blades and of methods of direction of the currents approaching and leaving the screw, is being determined experimentally, and it is to be hoped that, before long, we may see this instrument rival the better classes of turbine and exhibit an efficiency of 80 per cent. and upward. Thorneycroft has already done good work in this direction.

AËRONAUTICS.

It is the reduction of weight of hull and machinery, so remarkably exemplified in recent naval engineering, and the no less remarkable recent improvement in performances, that renders it more than possible that we may be on the eve of real advancement in *Aëronautics*.

In my last address, I referred to the work done up to that date, and endeavored to show how far the researches of Marey, of Pettigrew, of De Lacy and Houghton, had developed the experimental science of aëronautics, and how far the efforts of Dupuy de Lôme had supplemented the labors of the brothers Montgolfier, of Charles, of Greene, of Flammarion, and of Glaisher in actual navigation of the air. I took occasion to indicate what seemed to me to be the promise of the early future and the indications of ultimate success.

Since then, little or nothing has been done, either in research or in aëronautic practice; but Pole has made a study of the problem,

and from known data has determined what we may probably expect to see accomplished, when, as may soon occur, the modern methods of locomotive and marine engineering shall be applied to aërial steam navigation by means of balloons. He studies the problem as outlined by Lavoisier a century ago, 1783, as attacked by Giffard a generation ago, in 1850, and as so nearly solved by him and by Dupuy de Lôme during the Franco-German war. Both attained speeds of between 6 and 7 miles an hour in "*derigeable*" balloons.

Calculating, from known data, the necessary size of balloons to carry the demanded weights, obtaining by direct reference to known performance the probable resistance of the air-ship, taking the possible least weight of motor at 40 pounds per horse-power, net, 50 pounds gross and 75 pounds including the condenser, and allowing for nearly 20 tons of cargo, Pole finds that a balloon, of spindle form, 100 feet in diameter and 370 feet long, may be driven by this torpedo-boat style of machinery at the rate of about 30 miles an hour. An air-ship of one-half these dimensions would steam 20 miles, and one built on one-third scale 12 miles an hour.

These are certainly interesting and remarkable figures; but, as their author remarks, they come fairly and legitimately from existing data. Should the time ever come when the practical difficulties of construction can be fully overcome, it is evident that success in aërial navigation will promptly follow, and we may hope that the time is not far distant when this new product of modern mechanical engineering may become practically useful to the world.

To-day, however, man, with all his vaunted intelligence and with all his wonderful powers, is in this field beaten by every bird that flies, and even by so minute an insect as the gnat, which is only to be seen when disporting in the sunbeams.

Elmerus and Joseph Degnan have, as yet, no followers known to fame, and stand beside Bushnell and Fulton, who inaugurated submarine navigation, but are yet without successors.

CAPITAL AND LABOR.

In singular and discreditable contrast with all this gain in recent and current practice in engineering stands one feature of our work which has more importance to us and to the world, and which has a more direct and controlling influence upon the material prosperity and the happiness of the nation than any modern invention or than

any discovery in science. I refer to the *Relations of the Employers to the Working Classes* and to the mutual interests of labor and capital. It is from us, if from any body of men, that the world should expect a complete and thorough satisfactory practical solution of the so-called "labor problem." More is expected of us than even of our legislators. And how little has been accomplished?

Yet it would seem that the principles involved are simple and that the practical difficulties *should* be readily overcome. The right of every man to buy or sell labor wherever or whenever he may choose, and wherever and whenever he can make the best bargain, is one of those rights which are natural and inalienable. The right of every man to engage in any occupation, or to enter into any department of honest industry, to train his children for any productive occupation or to secure for them any kind of employment, is an equally natural and inalienable right. The privilege of accumulating property to any extent and by any honorable and legitimate means, is also naturally and legally accorded to every citizen. It would seem obvious that one of the first claims of the citizen upon the State is that he shall be absolutely assured of these as constitutional rights. Any infraction of such rights and any attempted contravention of such privileges, whether by individuals, by legally constituted corporations, or by associations unknown to the law, should be promptly dealt with, and so severely, whether the culprit be of high or low degree, that the offense shall not be likely to be repeated.

No legislation should be permitted that shall injuriously affect any morally unobjectionable industrial enterprise or that shall impede any fair commercial operation, whether in the exchange of commodities or the transfer and use of capital. Only such a tariff system, even, can be safely permitted as shall encourage fairly the growth of such new industries as are adapted to our climate, soil and other natural conditions.

The prosperity of a people is dependent upon their industry, integrity skill, and enterprise, as well as upon the natural resources of the country, and the object of every government and of all legislation is to protect the people in their right to a fair reward for their industry, skill and enterprise, to promote that mutual confidence that comes of real business trustworthiness, and to develop the natural resources and advantages of the State. The protection of the individual in his right to learn, to labor and to traffic; the encouragement of national enterprises, the diversification of indus-

tries, the promotion of the ability of the people to produce valuable materials and all kinds of products of the higher classes of skilled industry, the encouragement of invention and the making of the nation independent of all possible rivals or enemies in the production of whatever is necessary to the existence or the comfort of the people, are all perfectly proper objects of legislation. No legislation which neglects or opposes these objects can aid us. No legislation can serve the nation which aims to help either the employer or the employé, either the capitalist or the laborer, *alone*. No industry can permanently succeed which does not make both classes prosperous, and no state-craft is deserving the name which does not aim at the support of both. If either is discouraged and driven out of the field, business ceases and suffering results.

Again, force and intimidation have no place in matters of business. All legitimate operations, whether in commerce or manufactures, are the result of mutual agreement for mutual advantage. Strikes and lockouts, as well as their usual but shameful concomitants, intimidation and violence, are wholly out of place in our industrial system and should be repressed by every legal means, as absolutely opposed to the spirit of civilization and to the letter of our Declaration of Independence. The simplest principles of political economy and social ethics cover this matter fully. Labor, like any other salable possession, will have a value determined accurately by the great law of supply and demand, and the interruption of traffic in labor, and at the same time the compulsory interruption of production, in the end only result in serious injury to both parties to the controversy and to the whole country as well.

The introduction of a general system of arbitrament, the formation of unions between associated employers and associated employés, the diversion of the trades unions into their legitimate channels of usefulness, will ultimately, we may be sure, effectually reform all the existing abuses in this direction. Already workingmen are learning that strikes almost invariably cost far more than they gain; capitalists are beginning to understand that their pecuniary interest, as well as ordinary humanity, dictate careful consideration of, and respect for, the rights and interests of labor, and, ere long, when employers sustain labor exchanges in all our great cities, and when trades unions confine themselves to benevolent enterprises and the assistance of those members who desire to reach better paying fields of labor, we may expect to see every industry

settle down to a steady, unintermitted routine which will give maximum production, while every worker will have uninterrupted employment at rates of pay which will be the maximum value of the labor sold. If every boy were made familiar with Nordhoff and every man with Adam Smith and Spencer and J. Stuart Mill, we might hope that it would become universally understood that highest prosperity can only come when business can proceed without interruption by strikes, lockouts, or unintelligent legislation. A perusal of Eaton's excellent report on Civil Service suggests the thought that such a system is as desirable in every industrial organization as it is in the public service.

Grimm, in his life of Michael Angelo, says that three powers rule every state, and they are variously classed as "Money, Mind, Authority," as "Citizenship, Science, Nobility," or "Energy, Genius, Birth." I would say, in each individual, "Talent, Power and Character," or "Genius, Strength, Integrity," are ruling powers, but that we are yet to see them rule the State. That the time is coming we may, I am sure, both hope and believe, but a great change must first take place.

We need a Junius to write, a Burke to speak, and a Chatham to illustrate a real reform.

The elements of social economy are yet to become known to our people; the most obvious principles of statesmanship are yet to be learned by our legislators, and we have still to look forward to a time when our men of business and our working people shall be fairly and respectfully considered by those who direct public policy. Before the needed reform can be made productive of general good we must return to the original theory of our government—that all government has for its object simply the preservation of the rights of the people in their pursuit of the best life, the highest liberty and the purest happiness; that it should guarantee to all, of whatever race, creed, powers or sex, a common right to live, to learn, to labor and to acquire and hold property, with absolute freedom of thought, speech, and right-doing.

To attain all that we desire and to secure highest efficiency in our political and social system, we must have a business man's and a working-man's government. The professional politician and the machine system must become extinct. Our public policy and our law-making must be made subservient to industrial interests. The people, and not self-seeking ward politicians, must frame the code and direct the expenditure of public funds.

SYSTEMATIC PROMOTION OF INDUSTRIES.

And these considerations bring up the question:—How can so desirable a change in politics and in industry be brought about?

There is but one answer: By systematic and carefully planned encouragement of all industries, a system that shall illustrate those methods which are the true object of all government, a system, also, which shall supply means by which full advantage may be taken of all those opportunities, which present themselves to every citizen of the United States.

Such bodies as this must aid our legislative assemblies in developing a *Scheme of Industrial Organization*, that shall exhibit highest possible efficiency—one that will prepare the children and youth of the country to enter upon lives of maximum usefulness, and to do the work that may be given them to do with ease and comfort, while, at the same time aiding them to attain health, happiness and content, even if not independence and wealth.

It is easy to see what must be the leading features of such a system. Since the prosperity of the State and of the people depends upon the integrity, the skill and the industry of its citizens, it is evident that the cultivation of good morals, a keen sense of right and a high sense of honor are primary requisites; that the instruction and training of every youth in the art for which he is best fitted is essential; that a fair general education is equally necessary to afford sources of intellectual pleasure; that a reduction of the hours of labor to a minimum healthful length must give opportunity for continual self-improvement and for healthful recreation.

It is obvious that we must find ways of encouragement of those industries the success of which are best assured by our climate, our soil, our topography, and by our social and political conditions. We must take steps to secure by systematic legislation and by every other proper means a diversification of skilled industries and such a relative distribution of agricultural and manufacturing population as shall bring to each all the necessaries and comforts of life at minimum cost.

It is our task to study the soils, climates and natural resources of this wide land of ours, to learn what products of the soil and what manufactured articles can be made to give the best return for time and money invested, and then to systematically develop by public policy and private enterprise, every such industry, securing the highest skill, the most reliable labor and the finest artistic talent

by conscientiously cultivating them. Skilled labor has a steadier market and makes a steadier market than unskilled, and our effort should evidently be to lead the world in its development, cultivating all profitable manufactures which demand greatest skill and highest talent; encouraging a varied industry; making the expenditure of capital and labor on transportation and on coarse work a minimum, and making the most of every pound of raw material brought into our market before putting it on sale again. Any system of encouragement of domestic industries that may be adopted must evidently include a practical and fruitful plan of careful education and of regular training in the trades and arts capable of successful growth among us, making our people the equals, and, if possible, the superiors, of their competitors in other countries, in intelligence, skill, knowledge and enterprise. It must introduce new industries and diversify old ones. It must teach the child, train the youth, and protect the man from excessive outside rivalry.

Only when our whole population has become as intelligent, as skillful, and as well informed in every branch of every industry, existing or arising in the State, as any other people can possibly be, only then, may we rely safely upon profiting fully by all those advantages due to our natural position and resources.

Such a plan must be carefully considered by the sages of the community, and only adopted after deliberate study and thoughtful consideration. But a few general principles are readily discoverable. A half dozen years ago, at the request of a commission appointed by the State of New Jersey, of which commission I had the honor to be appointed secretary, I prepared a general outline of such a scheme as that which now interests us, and based it upon the following "platform":

Such a plan, to be satisfactorily complete, must comprehend—

A common-school system of general education, which shall give all young children tuition in the three studies which are the foundation of all education, and which shall be administered under compulsory law, as now generally adopted by the best educated nations and States on both sides the Atlantic.

A system of special adaptation of this primary instruction to the needs of children who are to become skilled artisans, or who are to become unskilled laborers, in departments which offer opportunities for their advancement, when their intelligence and skill prove their fitness for such promotion, to the position of skilled artisans. Such a system would lead to the adoption of reading, writing, and spell-

ing books, in which the terms peculiar to the trades, the methods of operation and the technics of the industrial arts should be given prominence, to the exclusion, if necessary, of words, phrases and reading matter of less essential importance to them.

A system of trade schools, in which general and special instruction should be given to pupils preparing to enter the several leading industries, and in which the principles underlying each industry, as well as the actual and essential manipulations, should be illustrated and taught by practical exercises until the pupil is given a good knowledge of them and more skill in conducting them. This series should include schools of carpentry, stonecutting, blacksmithing, machine work, etc., etc., weaving schools, schools of bleaching and dyeing, schools of agriculture, etc., etc.

At least one polytechnic school in every State in the Union, in which the sciences should be taught and their application in the arts indicated and illustrated by laboratory work. In this school, the aim should be to give a certain number of students a thoroughly scientific education and training, preparing them to make use of all new discoveries and inventions in science and art, and thus to keep themselves in the front rank.

A system of direct encouragement of existing established industries by every legal and proper means, as by the encouragement of improvement in our system of transportation, the relief of important undeveloped industries from State and municipal taxes, and even, in exceptional cases, by subsidy. It is evident that such methods of encouragement must be adopted very circumspectly and with exceedingly great caution, lest serious abuses arise.

This system should comprehend, perhaps, a Bureau of Statistics, authorized, under the law creating it, to collect statistics and information relating to all departments of industry established, or capable of being established, in the State.

I would place at the head of this whole system of aid and encouragement of all legitimate industries a great central University of the Useful Arts and Sciences which should be the directing member of the whole organization, furnishing higher instruction to the son of every citizen who can find his way to it, supplying the polytechnic schools and colleges with the most learned and talented instructors, aiding by scientific investigations the development of every industry, and serving as an attractive nucleus around which should gather the great men of every department to serve the State in that highest of employments, the instruction and training of our

youth, and by giving counsel to legislators and executive officers of every department of the Government, in concert with our already established National Academy of Sciences.

Washington urged the creation of a National University, a primary object of which should be the education of youth in the Science of Government. Jefferson, also, urged the foundation of "a National Establishment for Education," and John Stuart Mill has said: "National institutions should place all things that are connected with themselves before the mind of the citizen in the light in which it is for his good that he should regard them."

Experience at home and abroad shows that systematically conducted schools of art, and trade schools, are vastly more efficient and economical in the education and training of youth than the best-managed mill or workshop. Every operation can there be taught, and the learner made perfectly familiar with each detail, without causing the inconvenience and pecuniary loss which are sure to come with such an attempt in the shop.

Very much such a complete system of technical science of instruction and of industrial education has been incorporated into the continental educational structure, and there places before every child in the land the opportunity of giving such time as the social position and pecuniary circumstances of its parents enable them to allow it to devote to the study of just those branches which are to it of most vital importance, and to acquire a systematic knowledge of the pursuit which surrounding conditions or its own predilections may lead it to follow through life, and to attain as thorough a knowledge and as high a degree of skill as that time, most efficiently disposed, can possibly be made to give him. There is here no waste of the few months, or years, of to him most precious time, which the son or the daughter of the humblest artisan can spare for the acquisition of a limited education. Every moment is made to yield the most that can be made by its disposition in the most thoughtfully devised way that the most accomplished artisans and the most learned scholars, mutually advising each other, can suggest. One day in such schools as those here described is of more value to the youthful worker than a week in the older schools, or than a month in the workshop or the mill. Thus, while the fact is recognized that a general and a liberal education is desirable for every citizen, the no less undeniable fact is also recognized that few citizens can give the time to, or afford the expense of, a symmetrical general course, and that the interests of the individual and of the State

unite in dictating the provision of such systems and means of industrial education and training.

It is in consequence of the adoption of an intelligent and extensive system of the character of that which I would propose for our own country, that it has become now generally admitted that Germany is the best educated nation of the civilized world. (There is danger that the United States may, with reason, be reckoned the worst.) Germany is gaining a better industrial position daily; our own country is retrograding in all that tends to give manufacturing pre-eminence, except in the ingenuity, skill and enterprise of its people; and the one great, the vital, need of our people is a complete, efficient, and directly applicable system of technical instruction and of industrial training, if they are to avoid the successful and impoverishing competition of nations which have already been given that advantage by their statesmen and educators a generation earlier. The question whether this comparison shall remain as startling and as discreditable to the people of the United States in future years as it is to-day, is to be settled by the ability of our people to understand and appreciate the importance of this subject, by the interest which the more intelligent classes may take in the matter, and upon the amount of influence which thinking citizens and educated men, and the real statesmen among our legislators may have upon the policy and the action of the General and the State Governments. The promptness and energy which we may display in an effort to place ourselves in a creditable position among educated nations, will be the truest gauge of the character of the people of the United States. Judged by her progress in this direction, Europe is far in advance of us in the most essential elements of modern civilization. There, instead of standing aloof from each other, and instead of forgetting, as is too frequently the case in our own country, those great facts and those imperative duties which every statesman does, and which every citizen should, recognize, the governing and the educated classes have worked together for the common good, and have given Germany, especially, a vantage-ground in the universal struggle for existence and wealth which is likely, in the future, to enable that country for many years steadily to gain upon all competitors.

Our own work, thus far, has been desultory, sometimes ill-directed, and rarely thorough or systematic. Our "technical-schools," so-called, are often modified trade schools, and our few trade schools frequently aspire to the position of polytechnic schools, and both

classes are confounded in the minds of very many, even in the profession, and their work is seldom done with that maximum efficiency which can only come of intelligent organization and definite aims and fields of work. So it happens that while the system of general primary education is more widely spread and more effective than in any country in the world, and while we have a larger number of schools, in proportion to population, than perhaps any other country, we are nearly destitute of trade schools, and have extremely inadequate provisions for industrial education of any kind and for any class of our people.

This system of preparation of every citizen for useful work and a prosperous life being adopted, there remains to be considered what can be done to aid the great industries into the channels of which all this skill and training in the arts and applied sciences is to be directed.

GENERAL CONCLUSIONS.

A complete working system of preparation being inaugurated, all is done that can be done for the individual in the endeavor to place him on a fair vantage ground in the struggle for survival which is going on throughout the world. Beyond this he must trust principally to his own intelligence, skill, industry and frugality for success in the effort to secure the necessaries and comforts of life, and to acquire luxuries, a comfortable independence in old age, and the means of starting his children on a higher level than that which he has himself reached.

A plan for the encouragement of our industries and to secure permanent prosperity must include a general policy of legislation which shall aid the capitalist to safely invest his funds in manufacturing enterprises, or in agriculture; shall assist the workingman and the workingwoman to find remunerative and permanent employment, shall protect every one in the right to sell his capital or his labor at the best market value, wherever and whenever he chooses to offer it, and to give and to take in fair bargains without let or hinderance.

Such a policy must sustain every good workman in the effort to secure a good price for his labor, and every employer against every attempt to compel him to pay good wages for bad work or to surrender the control of his business or his property to any other man.

Legislation must be general, and must, so far as possible, avoid either direct or indirect interference with the natural currents of

trade. It must facilitate, not obstruct, natural industrial movements. The welfare of the people, and not of any class, rich or poor, must be studied.

The fruit of such a system as I have outlined will be fully seen only when all our labor is skilled and intelligent; when all our directors of labor are familiar with the science of their art, and when our men of science are all men applying science.

Rénan, in his autobiography, expresses his conviction that succeeding generations will be taught principally natural sciences, for the reason that the truths learned in their study have more importance to mankind, and have a deeper interest than the facts of history or the accumulated stores of general literature.

Men of Science and men of Art, too, are becoming known and acknowledged as of most importance to mankind, and as the principal reliance of the race in its terrible struggle against poverty, disease, misery, and death. The influence and the power of men who devote themselves to the study of the phenomena of nature, and of those who make useful application of a knowledge of Nature's facts, laws and forces, must inevitably and continually increase so long as civilization shall continue to advance.

The world will finally reward most nobly those who thus most nobly strive to forward its highest aims.

THE RAIL CAMBERING ARRANGEMENT OF THE LACKAWANNA IRON AND COAL CO.

BY

W. K. SEAMAN, SCRANTON, PA.

THE subject of the treatment of steel rails after they leave the rolling train is one which has, perhaps, received more of the attention of rolling-mill engineers than any other detail of their manufacture; and the fact that so many diverse means are at present used, is sufficient evidence that none has, as yet, been made wholly satisfactory.

The rail as delivered from the rolling train is substantially straight; but if it now be simply allowed to cool, it assumes a curve, due to the lack of symmetry of its section and its consequent unequal cooling.

To correct this result, the prevailing practice is to give it, by some means, a contrary curve while still hot, so that it will, in cooling, approximate the straight form. Whatever "kinks" may then exist are taken out by the cold-straightening presses or "gags."

Regarding this latter process I quote from a paper read before the Iron and Steel Institute of Great Britain by Capt. Wm. R. Jones, of the Edgar Tompson Steel Works, as follows: "The present plan of straightening by presses is certainly a barbarous one, and will, sooner or later, be superseded by passing the rail through a series of rolls."

All experts are, I believe, agreed that this cold-straightening process is essentially bad; any treatment which contemplates a reduction of its necessary amount is, therefore, worthy of attention.

The "kinks" in a cold rail are traceable to two general causes: first, unequal heating and cooling; and second, to imperfect mechanical manipulation of the product after it leaves the train.

The first of these causes it is practically impossible wholly to overcome.

In the design to be here exhibited, the writer has endeavored fully to meet the second, and, further, to produce a series of machines thoroughly mechanical in detail, no more liable to excessive wear and repair than other rail mill machinery, and capable of being

worked to the full capacity of the most successful rail trains by one or, at most, two men. Cordially inviting their candid criticism, he asks his listeners to be the judges of how far he has succeeded.

In the accompanying drawings (in which all minor constructional details have been omitted), Fig. 1 is a general plan of the entire apparatus;—those of you who are familiar with the "Gustin" cambering machinery, will observe its similarity as far as the first hot-bed. The details are essentially different, and it is with these that the present paper has chiefly to deal.

In Fig. 1, *A* designates the mouth of the switch, which receives the rail from the finishing rolls whose axis is *MM*—the switch being made to swing on the pivot *T*, so that its mouth can be adjusted to receive the rail from either of the finishing passes, indicated by the dotted lines.

On the switch are secured a series of "idler" guide rolls, *BB*, etc., which guide the rail to the first pair of driven or "grip" rolls, *C*, which forward it thence through the guide rolls B^1 to the second pair of grip rolls, C^1, thence through the guide rolls, B^2, to the third pair of grip rolls, C^2, and so on successively till it reaches the cambering or bending machine, *E*, which delivers it on the hot-bed with the required curve.

It will be seen that a second hot-bed is provided, and that between the rails of the first bed is placed the necessary machinery for transmitting the rail across this bed, and to the second cambering machine and its hot-bed.

Two hot-beds are necessary; otherwise the capacity of the apparatus for properly cooling the rails would not equal that of the train for rolling them, and the latter machine would necessarily be restricted in output.

It is thought highly advantageous to have two cambering machines for the following reasons:

1st: It is thereby rendered possible to transmit the rail across the first bed, and to the second cambering machine, while it is still straight; the bending roll of the first cambering machine being invariably thrown back, so that this machine acts simply as a pair of grip rolls when the second cambering machine is being used, and the second bed is being filled with rails.

2d. By the use of two cambering machines it is rendered possible to continue work at the rail train, in case of the derangement, from any cause, of either cambering machine. *RR* (Fig. 1)

indicates the main or engine shaft driving the entire arrangement; the saw countershaft (not shown) constantly in one direction by belting from the pulley U; the cambering machines EE^1 and grip rolls H by plain miter-gears, constantly in one direction; the drum shaft II through the reversing friction clutch O in either direction at will, and the grip rolls CC^1,C^2,C^3, through the reversing friction clutch L, in either direction at will.

With the drum shaft, II, we shall have little further to do; its function is simply to slide the rail over the surface of the hot-bed in either direction from the center by means of operating traverse buggies running on top of the rails of the bed.

These buggies are drawn back and forth by endless wire ropes passing over sheaves at either end of the bed, and around the drums, TT, T^1,T^1, at the center several times in the ordinary way. By means of crab couplings on the drum shaft, either pair of drums can be operated at will while the other pair stands still; these couplings being reversed only, of course, when one bed is filled with rails and the other is to be used.

By means of the grip rolls, C^1,C^2 and C^3, the rail is adjusted to and held in the proper position for having its ends cut off by the hot saws DD. These saws are suspended in rigidly trussed swings, and are fed across the rail by a hydraulic cylinder fixed on the central countershaft stand, S^1. The swings and feeding connections are of ample proportions, and are so designed as to insure steadiness and freedom from vibration to the saw mandrel.

Both the friction reversing clutches, O and L, and the hydraulic cylinder feeding the saws, are operated by hand levers, Y, Y^1, Y^2, conveniently arranged upon the elevated working pulpit, V. The operator faces the rail as it lies before the saws, looks toward his right, whence he receives it from the train; in front, when he adjusts it for sawing, and cuts off the ends; and toward his left, when he traverses it across the hot-bed, after it has passed through the cambering machine.

Having thus described the general arrangement, the details, beginning with the "grip" or forwarding rolls ($CC^1C^2C^3$ Fig. 1) will next be considered.

Fig. 2 is a transverse vertical section through the axes of a pair of the rolls; Fig. 3 is a vertical section through yy, Fig. 2.

But one roll, b, of each pair of grips is driven; the other roll, d, runs free on its axle. The driven roll, b, runs in fixed bearings, top and bottom, and receives its motion directly from the line shaft, J,

situated vertically below it, through a pair of miter-gears. The roll *d* is capable of all the required adjustment for different rail sections in the following manner: As is shown in Figs. 2 and 3, the axle on which it turns is supported top and bottom by the frame of the machine; these two supports have a common axis, while that portion of the shaft around which the roll *d* revolves is eccentric with them, as distinctly shown in Fig. 3. Now to vary the distance between the two rolls, it is only necessary to turn the shaft *E* in its supports, through a portion of a revolution, and clamp the shaft firmly in the desired position by the nut *N*. A square end is provided on the shaft, above the nut, whereby the shaft is turned in its supports and held *while being clamped.*

The rail enters the machine as indicated by the arrow, its weight being carried by the web on the rolls *w* (Fig. 1), throughout the entire arrangement.

These rolls are so placed that for all common sections of rails their position does not require adjustment of any kind.

The double-cone-shaped casting (Figs. 2 and 3) forms a perfect protection from scale to the bearings and gearing below them; the scale delivering down their sides and away from the machine.

It will be seen that the shaft *J*, inaccessible, apparently, at first sight, can be removed without disturbing the sole plate *I*, which is firmly bolted and sulphured to the foundation. Without calling special attention to this point for each machine, it may be here stated that this feature has been embodied in all the details whose positions are over the shaft *J*. Further: the bearings of the shafts $J\,J^1$ are all in accessible positions for inspection and oiling; this position of these shafts was selected because it did away with so much mechanism necessary in existing arrangements.

The cambering machines, Figs. 4, 5 and 6 (plan and two sectional elevations), situated at *E*, E^1, Fig. 1, will next be considered.

They are simply combinations in one machine of two pairs of grip rolls, $b\,d$ and $b^1 d^1$, with a bending roll *j*. One roll, $b\,b^1$, of each pair of grip rolls is driven directly through miter-gears from the shaft J^1; these rolls run in fixed bearings, are in no way adjustable, and are the only driven rolls in the entire machine. The rolls d, d^1 are adjustable by the eccentric arrangement before described; the roll *j* has precisely a similar means of adjustment, but it is retained in the desired position by the lever *n*, running over the slotted segment *p*, and clamped by the nut *o*.

This segment can be graduated (from practice) for the various

rail sections, and the adjustment of the lever n gives the required variation in camber in a most simple manner.

The ends of the rail (where sharp upward bends are liable to exist as it is delivered from the train) having been invariably sawn off before it reaches the cambering machine, it is admissible to put the upper bearings of the rolls of this machine in a continuous frame, *I*, *above* the rolls; by this means a much more rigid construction is obtained than is possible where both bearings are *below* the rolls; also, by placing the upper bearings of the shafts above the work they are protected from scale—two important features. The lower bearings and miter-gears are completely protected from scale by the shrouding casting z, which delivers it in all directions, away from the rolls.

One set of the guiding rolls ($B, B^1 B^2 B^3$, Fig. 1) are shown in detail by the upper portion of Figs. 10 and 11, both of which are vertical sections through the axes of the rolls.

As shown in Fig. 1, the several sets of guide rolls, B, B^1, etc., are mounted in appropriate frame castings, but the rolls and their adjustments are precisely like those shown in detail by these figures.

The roll h runs freely on the straight stud r, which extends through a boss on the frame of the machine, and is held in position by the nut s. The adjustable roll i runs free on a stud v, similar to r, except that it has an eccentric offset shown at t, Fig. 11; by turning this stud in its boss, it will be seen that the roll i, revolving about its axle v, will be moved toward or away from the opposite roll h. In each pair of rolls throughout the arrangement, one roll runs about a fixed center, while the other has all the required means of adjustment.

The non-adjustable rolls are in one line, vertically over the shafts JJ and $J^1 J^1$; if, therefore, these are once properly aligned, they will retain such alignment, under all conditions of adjustment of the other rolls, and thereby is obtained a rigidly straight guide for the moving rail.

The essential details as far as the first hot-bed have now been described; the machinery *in* this bed, and for the purpose of transmitting the rail over it to the second cambering machine, will next be considered. The requirements of this mechanism are twofold: first, while the first bed is being used, it must entirely disappear from above the surface of this bed in order to allow of the free transverse motion of the hot rails toward the ends and from the center of the bed, where they are delivered by the cambering machine.

Second, when the second bed is being used, the mechanism must appear above the surface of the first bed in order to grasp and forward the rail across said bed to the second cambering machine and its bed. This mechanism consists simply of one pair of grip rolls (*H*, Fig. 1) and four sets of guide rolls (*GGGG*, Fig. 1) similar to those described, with the addition of means for raising and lowering them above or below the level of the bed, according as to which bed is being used.

Figs. 7, 8, and 9 (plan and two sectional elevations) show the rising grip rolls situated at *H*, Fig. 1. The action of this pair of grip rolls is essentially the same as that of the others; its construction is, however, necessarily different, to allow for the required vertical motion, which is provided for as follows: The lower bearing of the driven roll shaft *c* is fixed in the plate *M* of the machine. The upper bearing of this shaft and the two bearings of the adjustable roll shaft, *e*, are carried in a single casting, *R*, which is capable of vertical motion, carrying the rolls with it, on the four fixed guide-posts, *SSSS*, in a manner similar to that employed for the platen of an ordinary hydraulic or screw press. The driven roll shaft *c*, obtains its motion by means of a "splined" bush, c^*, to which the driven gear is keyed, through which the shaft, *c*, can freely move in the direction of its axis; but from which, by means of a "feather" key, c^2, it obtains its rotary motion.

The casting, *R*, carrying the three bearings, the rolls and attendant parts, is supported through the links, $j^2 j_2$, at the ends of two levers, $K^2 K^2$, which are keyed to the horizontal rock shaft, l^2, running in fixed bearings, on the sole plate. On the opposite ends of these levers, $m^2 m^2$, are the counterweights, *T*, which practically balance the weight of the vertically moving parts.

To raise or lower the pair of grips, it is only necessary to operate the lever, *V*, and, since the parts are balanced, the power necessary to do this is only that due to the friction of the moving parts.

Figs. 10 and 11 show a pair of the tilting guide rolls (*G*, Fig. 1). The two vertical rolls, *h* and *i*, and the carrying roll, *w*, are mounted on a casting which swings about the rock shaft, *L*, and which is counterweighted at *N* and *N*, so that, in operating, the friction only has to be overcome.

FF, Fig. 11, show in section two rails of the first hot-bed, the rolls being shown in their upper position; to lower them, the whole casting supporting them is tilted down by means of the

lever, O, and link, P, to the dotted line indicating their position when the first bed is being filled with rails.

A fixed lug, R, is provided, against which the swinging casting abuts in its upper position, and the rail, always moving in the direction indicated, tends to drive it against this lug; further, by placing the counterweights, NN, out of center as shown, a tendency is produced that keeps the casting against the lug after the rail leaves the rolls.

The several sets of tilting guide rolls and the single pair of rising grip rolls, are all operated by means of a lever, W (Fig. 12), attached by links, P, to convenient points on the several castings as shown, and worked from a point outside the hot-bed.

After having passed through the several sets of grip and guide rolls, $C, C^1, C^2, C^3, B, B^1, B^2, B^3$ (Fig. 1), the rail will contain no bends in a *horizontal* plane; if, however, from irregular working of the rolling train, any kinks have been put in the rail in the *vertical* plane, these will still remain in it when it reaches the cambering machine.

To take these kinks out is the function of the straightening machine, situated at P in the general plan, Fig. 1, and which is illustrated by Figs. 13 and 14, the former of which is a side elevation; the latter a vertical section through XX, Fig. 13. The machine contains two *entirely distinct* sets of rolls, as shown in Fig. 14, each composed of five rolls—one set, $GG^1G^2G^3G^4$, acting upon the head of the rail, the other upon its flange.

None of the rolls of this machine are driven, the grip rolls situated on either side of it serving to drive and draw the rail through without further aid.

Each roll is keyed rigidly to its respective shaft; the shafts have their bearings in the eccentric bushes, II^1, etc., which in turn find their support in the frame of the machine. It will now be seen, upon a moment's consideration, that if these eccentric bushes be turned in their bearings, the positions of the centers of the rolls will be altered relatively to one another. From each of the bushes, $I—I^4$, extends an arm $J—J^4$, and from J^2 extends a hand lever K, which connects with the arms J and J^4 by a rod, L, and with the arm J^1, by a rod, M—the arm, J^1 being connected to the arm J^3 by a rod, N. By pushing the lever K in the direction indicated, all the bushes, $I—I^4$, are turned in the direction of the arrows, and the rolls GG^2 and G^4 are moved upward, while the rolls G^1 and G^3 are

moved downward. By pushing the lever in the opposite direction, the motion of adjustment is, of course, reversed.

The adjustment of all the rolls *toward the axis of the rail* is necessary, from the fact that the web of all sections of rails runs on the constant level of the carrying rolls, *ww*, etc. (Fig. 1), and this level must necessarily be maintained through the straightening machine.

In the arms, II^1, etc., are formed segmental slots, *c*, through which screw studs provided with nuts, *e*, extend from the frame of the machine. When the rolls, $G—G^4$, have been adjusted, the nuts, *e*, are screwed down, locking them in the desired position, and thereby retaining the roll centers as required for any given section of rail. Also, screwing down the nuts, *e*, relieves the arms, *II*, etc., and their several connecting links, of all strain; their function being simply to retain the eccentric bushes in their relative positions, when the adjustment of the rolls *is being made*.

It would seem that a machine built upon this plan, but much heavier, might be advantageously tried on cold rails. This, however, is merely a suggestion, on which I should be pleased to hear the views of some of the gentlemen present. By the use of this straightening machine, and the series of aligned guide rolls, the rail is delivered *straight* in both planes to the cambering machine, which gives it its required curve, and delivers it upon the bed. The hot-bed construction adopted with this arrangement is shown by Figs. 15, 16, 17 and 18.

Fig. 15 is a general plan of a portion of the bed. *D*, *D*, *D*, etc., are bed-plates having facing strips on their upper surfaces, which receive the columns supporting the bed rails, *AA*, etc.

To the central row of columns, which are firmly trussed to the adjacent bed-plates, as shown on Fig. 18, the rails, *AA*, are firmly clamped at their middle points, and are free to expand from these points each way toward their ends by being supported on the columns of the rocking construction shown by Figs. 16 and 18. The lower section, C^1, of these columns is firmly keyed to the bed-plates; the upper section, C^2, rocks about the trunnion C^6, which has its bearings in the two *Ys* formed in the lower section. By separating the counterweights, C^4C^4, as shown in Fig. 16, the upper section is prevented from tipping sidewise, while it is free to rock under the expansion of the rails of the bed when the latter is loaded with its burden of hot rails.

Now since the *faced* bed-plates can be set perfectly level when

they are put down, we can, by facing the bottoms of all the columns to a common template, measured from the rough surface c^5, insure a perfect level to the upper surface of the hot-bed, with the single-faced joint at the foot of the columns.

Care, however, must be taken to keep the sections of columns measured, in pairs together, otherwise the variation in the castings will affect the accuracy of the work.

The trunnion C^6 and its *Ys* are rough cast, and are protected from scale by the projecting wings, C^2, Figs. 16 and 18.

The columns are attached to the bed-plates by keys and pins, all of which are fitted in "cored" holes, making a comparatively inexpensive construction. The bed is made unusually high, in order to allow a free circulation of air beneath it; thereby obtaining an approximately equal cooling effect, upward and downward.

The details of the arrangement having been thus described, the following claims are made for it:

1st. The maintenance of perfect parallelism between the axes of the rolls in all conditions of adjustment.

2d. Dispensing with the necessity of different sets of change rolls for the various rail sections.

3d. The means of obtaining a variable camber for different rail sections, with but the one simple adjustment of the lever of the bending roll of the cambering machine over its graduated arc.

4th. In the cambering machine, by the use of the continuous upper frame *above* the rolls, a much more rigid construction than has been hitherto obtained.

5th. The efficient provision for the exclusion of scale from bearings and gearing.

6th. A rigidly straight guide for the moving rail by making one of each pair of rolls run about a *fixed* center, while the opposite adjusts toward it.

7th. The minimum of necessary labor for operating.

8th. The minimum of necessary driving gearing and shafting.

9th. The provision for taking vertical kinks out of the rail by the use of the straightening machine; and,

10th. The provision of a hot-bed that will remain level under the variable temperatures to which it is subject.

The strongest criticism that has been urged against this arrangement is, that the machinery must be well maintained, and that it will therefore rapidly deteriorate in the rough usage it will receive in the average rail mill. In replying to this I cannot do better than

quote the words of the late A. L. Holley, Esq. In a synopsis of his lectures, delivered at Columbia College in 1879, he says: "An iron-works is a comparatively good place to maintain good engines. The objection of bad attendance is simply atrocious"

I ask, if true of engines, why not true as well of this machinery? It needs fair attention, nothing more; and I claim that one competent man, to have exclusive charge of it, is all that is necessary to its successful manipulation.

It may be well to here call attention to the facts which an inspection of the drawings will show: 1st, that any one of the series of machines can be introduced into existing arrangements, independently of the others. Particularly is this the case with the cambering machine, forwarding rolls and straightening machine; 2d, that the arrangement as a whole can most readily be adapted to the handling of double, triple or quadruple lengths, in the "direct rolling" process now, to a limited extent, coming into vogue in this country.

In conclusion the writer would say that the Lackawanna Iron and Coal Co. now have the whole arrangement in course of construction agreeably to the designs that have been here shown; it will be erected at the earliest available stoppage of the rail mill, a somewhat uncertain date, as rolling-mill superintendents will readily understand.

Through the kindness of Mr. C. F. Mattes, the General Manager of the company, who has throughout rendered every available aid, those especially interested in the subject are cordially invited to visit Scranton for an inspection of its practical working after it is put into operation.

DISCUSSION.

Mr. Durfee.—I would like to ask the author of the paper what provision he has made in the machine, if any, for this condition of facts? It is well known that rails are never finished at a uniform temperature, when compared one with another. I presume it is the intention to give by this machine a definite curve to the hot rails, which is of such character as will cause the rails to become straight when cold. Now if such is the purpose of the machine, every rail must pass through it at a temperature suited to the degree of curvature in order to uniformly produce straight rails, which uniformity of temperature cannot practically be maintained.

Mr. Seaman.—In reply, I would say that it is not expected that

this machinery will produce a perfect product. It only points toward an improvement, and if we obtain such improvement in the product with a much smaller force to operate it, we will do a good thing. We cannot expect to have straight rails when they get cold, on account of the very reasonable suggestion made that it is impossible to maintain a uniform temperature.

Mr. Durfee.—Then, Mr. President, all the rails will have to pass some one's inspection, and all those which are not straight will have to be straightened in the ordinary way. Now, while it is known that one sturdy straightener, with a boy as an assistant, will straighten 70 tons of rail in one day, it does seem to me that this is a very large amount of machinery to get rid of that amount of handwork.

Mr. Seaman.—This machinery does not contemplate doing away with the straightening process. It contemplates the handling of the rail from the train to the straightening press. During that journey of the rail from the train to the straightening press, it is under the control of one man. I have visited several works where they were in process of getting this thing up. At one I have seen the rails dragged from the rolling train to the hot-bed by four men. At other works this same general arrangement is used, but the details are essentially different, and the details are what have given the trouble; that is, they are not mechanical. I cannot see anything unmechanical in this.

Mr. Durfee.—I think, Mr. President, that the author of this plan has shown a great deal of ingenuity in his general mechanical arrangements. But my objection is this, that there is a vast amount of machinery to do very little work comparatively. Two men, or one man and a gag boy, will straighten cold 70 tons of rails in a day. I have had that amount of work done repeatedly with that force. As regards the handling of the rail from the train to the hot-bed, in many mills simple arrangements are devised for that purpose, and the arrangement proposed here with buggies traveling to carry the rails lengthwise from the hot-beds is, I should think, very satisfactory indeed; but the machinery for getting the rail to that handling arrangement (and, really, I think it appears that that is all it does), it seems to me, is unnecessarily elaborate and expensive.

Mr. Hunt.—Not having had the pleasure of hearing the description of the machinery, I cannot express an opinion of Mr. Seaman's arrangement. But in answer to my friend, Mr. Durfee, I would say that I think one of our greatest troubles in rail manufacture

to-day, is to get a perfectly straight rail; that is, they will put some more kinks into the rail that passes under their press. Railroad engineers are becoming more and more particular, so that we are in constant discussion in regard to rails, they thinking they are not good enough and we insisting they are a little too good. The hot straightening is a point that will bear the putting in of a good deal of machinery.

Prof. Robinson.—One point should not be overlooked in the discussion, and that is that in practice we have the trouble of the breakage of rails. The first bend is one step toward the destruction of the rail, if it is made when the rail is cold, whereas if it is hot there is less injury to the rail by bending it. Any roadmaster will tell you he would prefer to have his rails straightened hot, in preference to being bent cold.

Mr. Durfee.—The simple system of bending rails hot on a curving plate allows those rails to cool with very little curvature in them; as little, I think, as would result from all this machinery, if the work is carefully done. It is the constant practice in mills for rails to come from the train to be carried by some means, automatically in many mills, to the straightening plates. They are there sawed off and curved to a definite curvature and the curvature which is found by experience to be that which will enable a rail of average temperature to cool as straight as possible. I think that the ordinary system of practice is quite as satisfactory as this expensive mass of matter would be.

Mr. Seaman.—In reply to the last observation, I would say that the various systems of cold straightening plates compel every rail, whether it weighs 56 pounds to the yard or 30, to take the same curve. Now does it look reasonable to any one familiar with the business that those two sections, varying as they do 26 pounds in the length of one yard, will have the same variation in cooling that is due to their difference in weight?

Mr. Durfee.—In reply to that observation, I would say that I have constructed five or six rolling mills, and I have never yet built one in which I was not able to vary the curvature of the hot rail at pleasure.

Mr. Seaman.—I have seen two of that nature. In the Lackawanna Coal and Iron Company's Works at Scranton we have an arrangement to change that adjustment, but it is never used.

Mr. Durfee.—I will describe a very simple means I adopted and found to work very satisfactorily. A couple of rails were rolled

and allowed to take such curvature in cooling as they naturally would. Those two rails were then bolted together with their flanges uppermost, and used as a curving plate. To change the curvature for different sections of rail, little pieces of bent sheet iron of different sizes made to clip the flanges of the rail were slid on when the section of rail being made was changed.

Mr. Strong.—I rise to the point of order that the machine which he has used is not before the Society. I am not a rolling-mill engineer, and as to the merits of this machine, I would not like to give my opinion; but as to the mechanical details carried out, and as to the general way in which the gentleman has described the machine I must compliment him.

Mr. Durfee.—I do not consider that the point of order is well taken. The author of the paper said that it was not reasonable to suppose that rails of varying section could be curved on the same curving plate and cooled in a straight line. My remarks only tended to show that in my own practice I never made such a construction; that I did not regard such a construction as necessary, and to explain very briefly and simply the construction I had adopted. I had no intention of advocating my own plan in preference to any one else's, and no intention of criticising unnecessarily or severely the plan which the gentleman has so very ably elaborated. I have no feeling in the matter at all. I only wish to present the facts which I think are essential to the operation in view.

The President.—The gentleman was entirely in order. He has a perfect right to make a comparison of that and other machines.

Rail Cambering Arrangement

designed for the

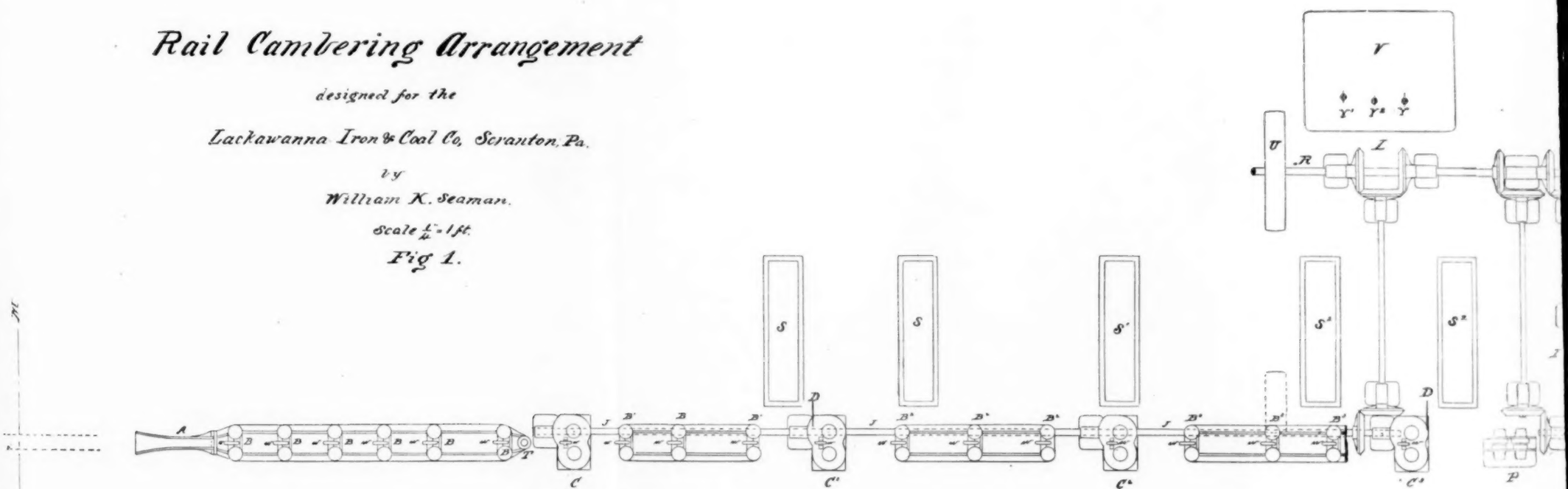
Lackawanna Iron & Coal Co, Scranton, Pa.

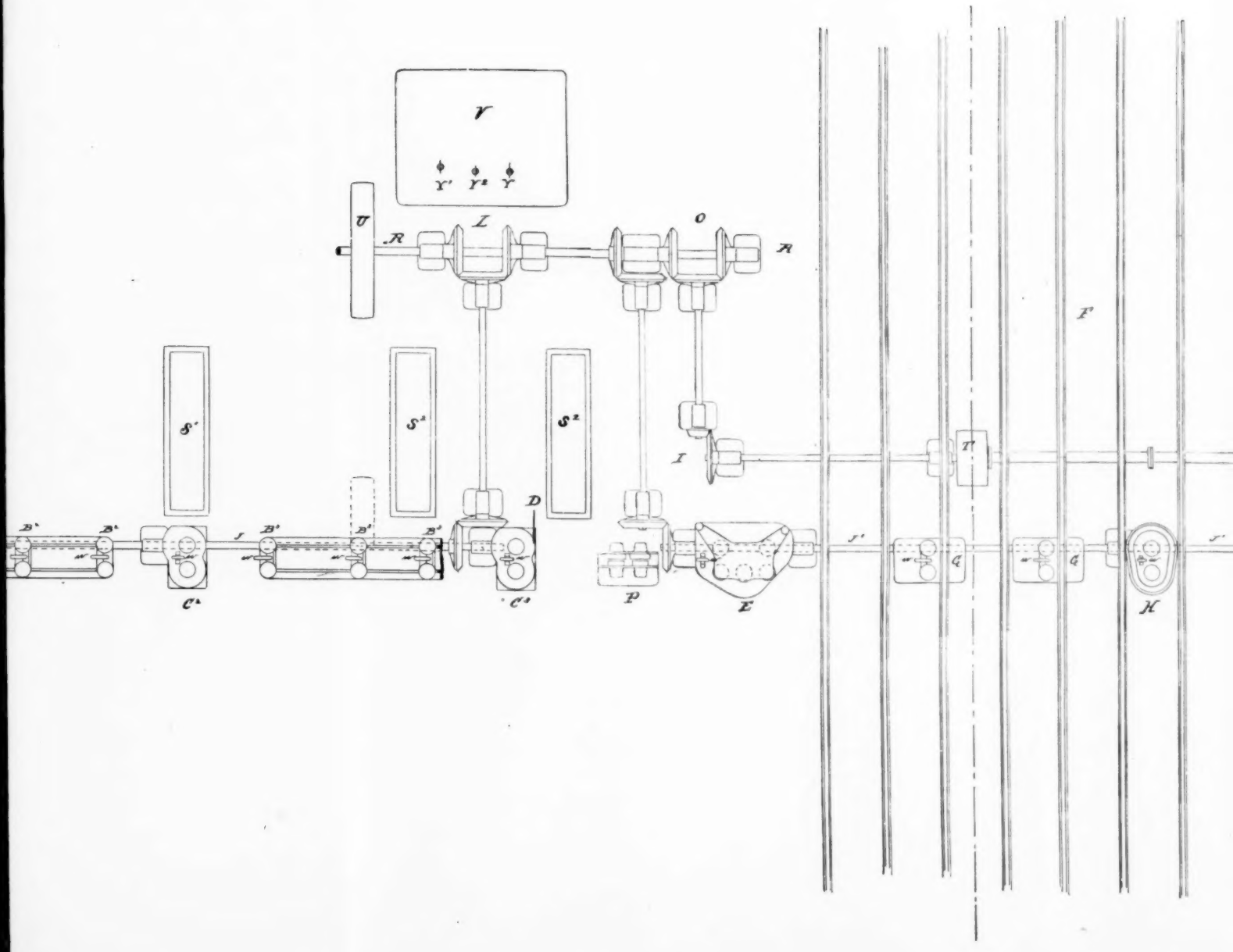
by

William K. Seaman.

Scale $\frac{1}{4}$" = 1 ft.

Fig 1.

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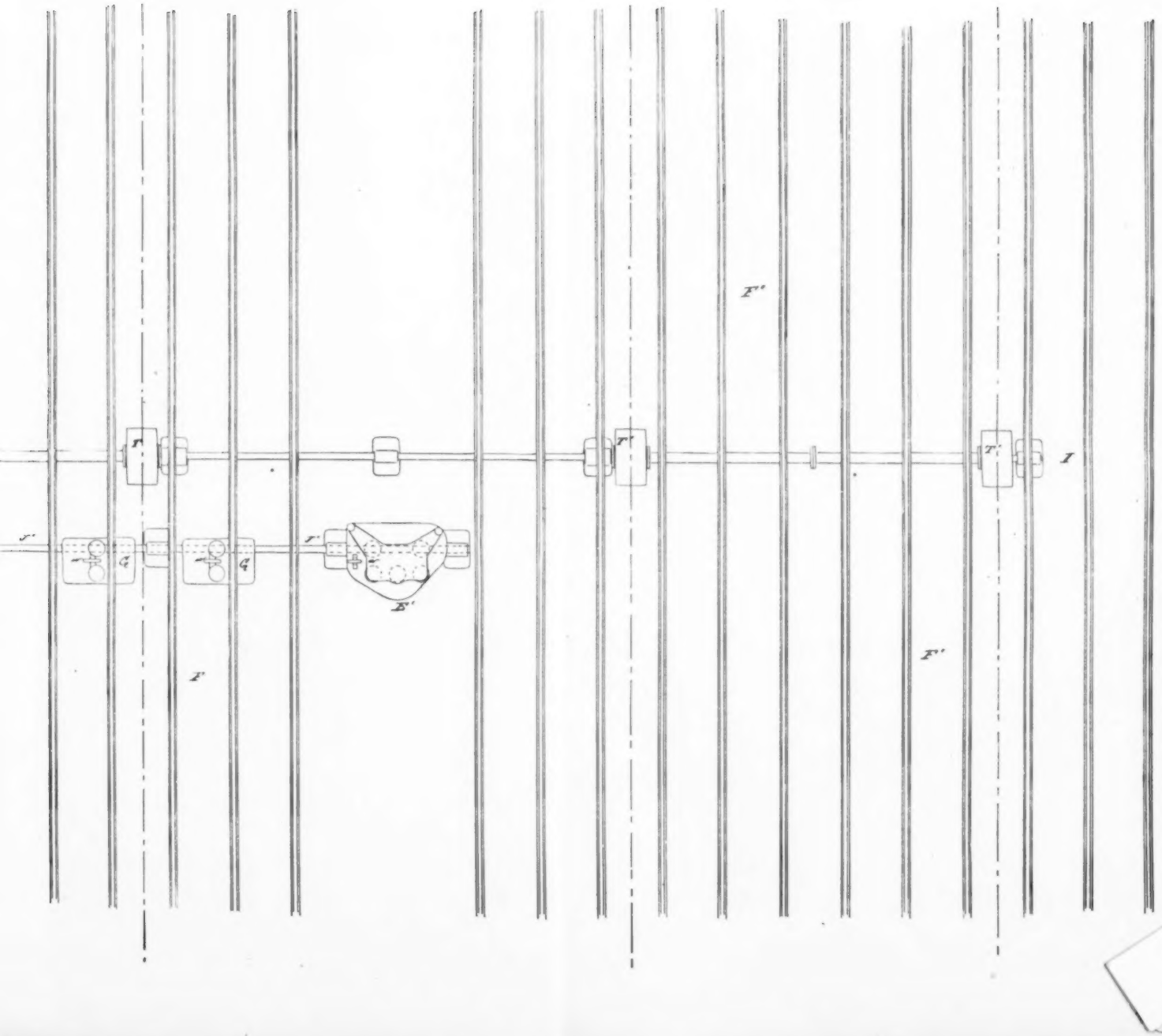
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Fig 2.

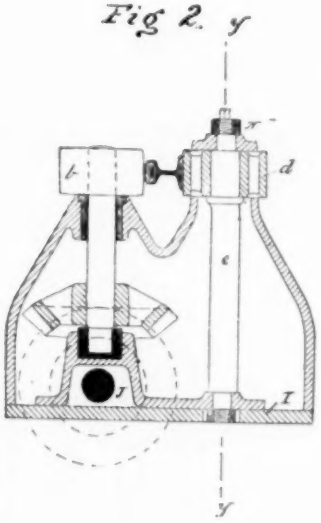
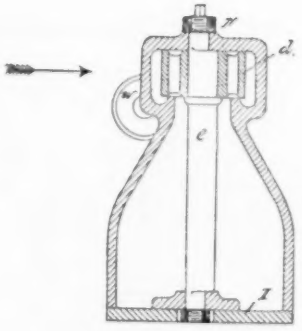
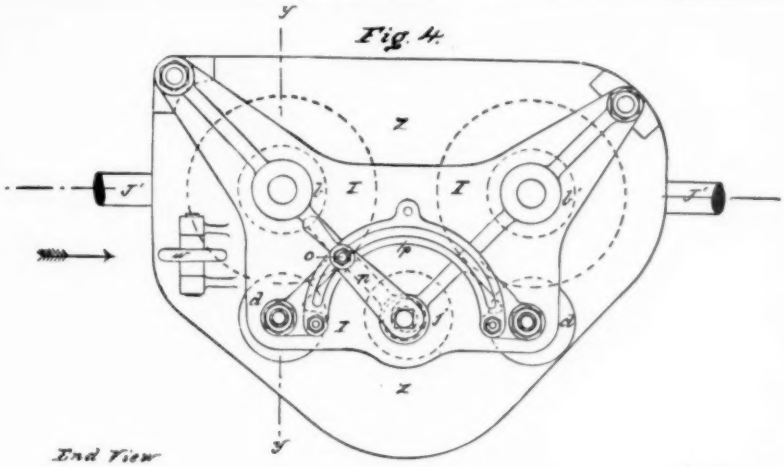


Fig 3.



Grip Rollers. (C. C' C² C³ — Fig 1.)

Fig. 4.



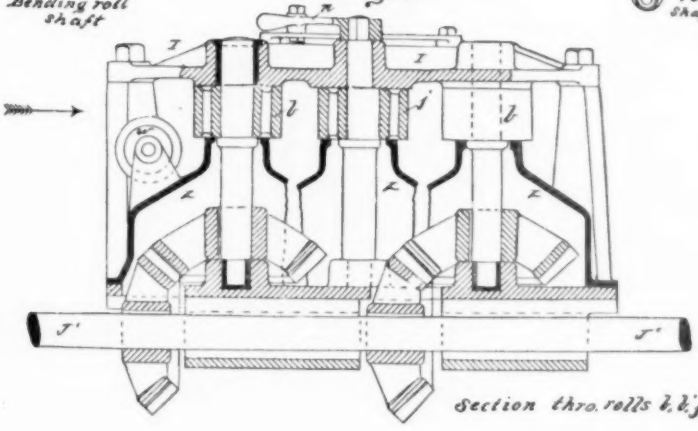
End View

Bending roll shaft

Fig. 5.

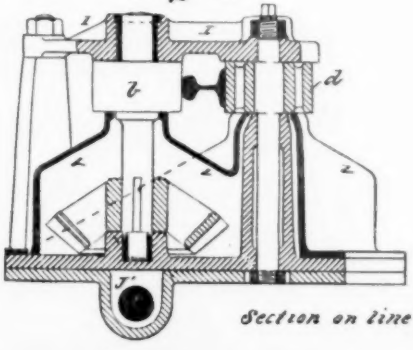
End View

Grip roll, Shaft.



Section thro. rolls l, l', j.

Fig. 6.



Section on line y y.

Camlering Machine. (E, E' Fig 1.)

Fig 7.

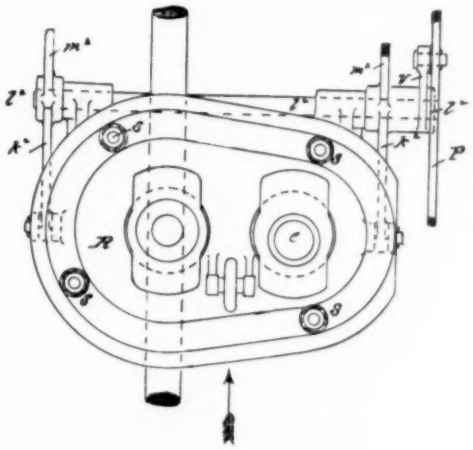


Fig 8.

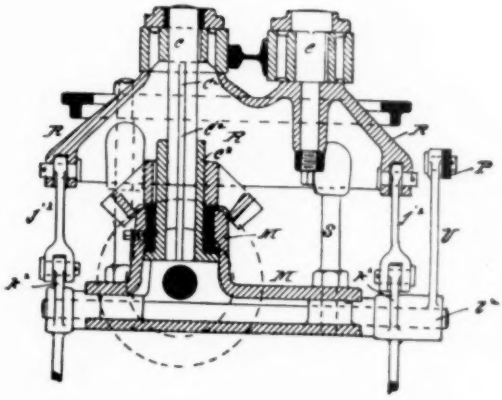
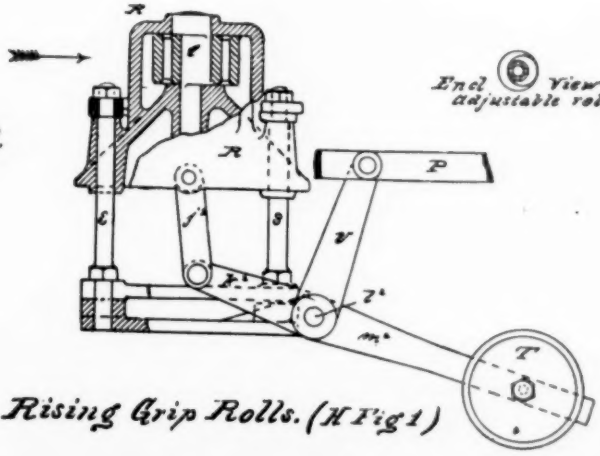


Fig 9.



End View adjustable roll shaft.

Rising Grip Rolls. (H Fig 1)

Fig 10.

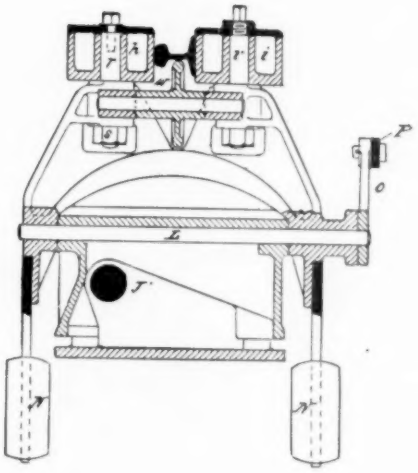
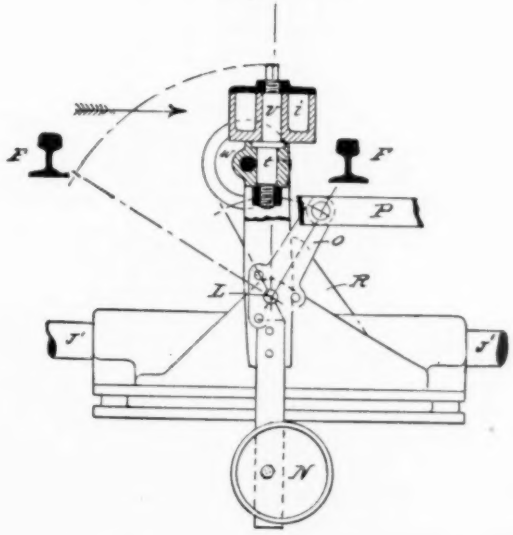


Fig. 11



Tilting Guide Rolls. (C.C.C.C. Fig 1)

Fig 12.

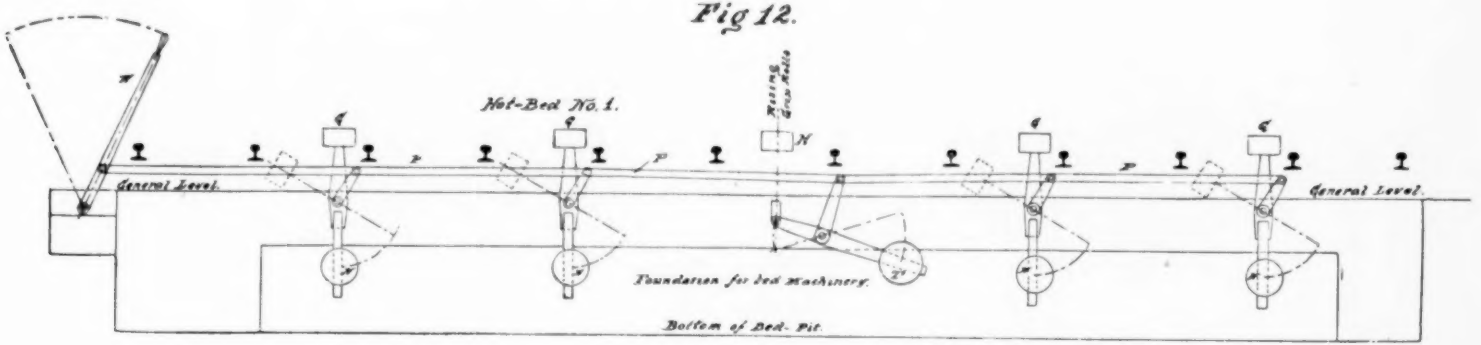

Hot-Bed No. 1.
Raising Gear Motion
H
General Level.
General Level.
Foundation for Bed Machinery.
Bottom of Bed-Pit.

Fig 13.

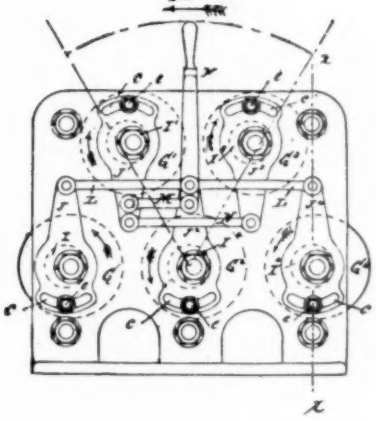
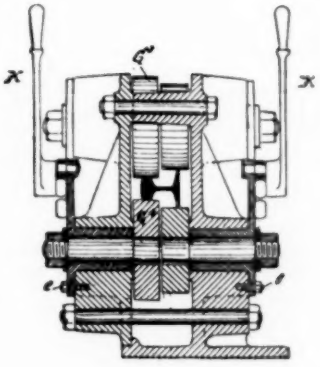


Fig 14.



Hot-Rail Straightening Machine. (Fig 1)

Fig 15.

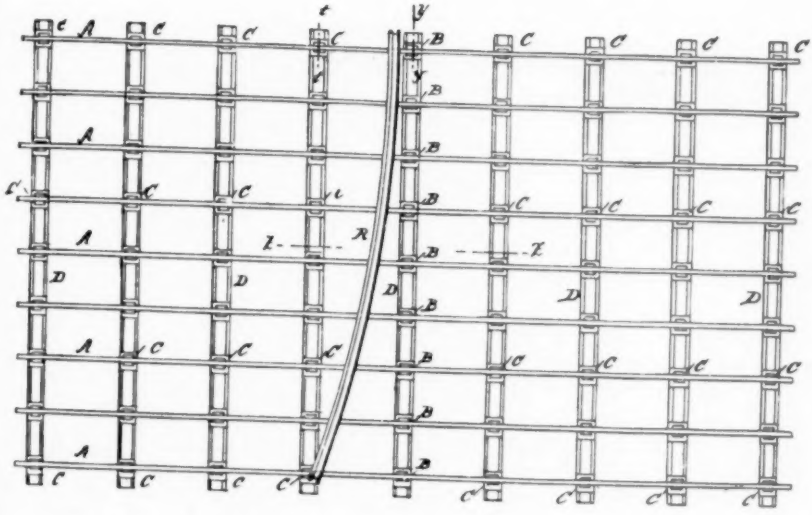
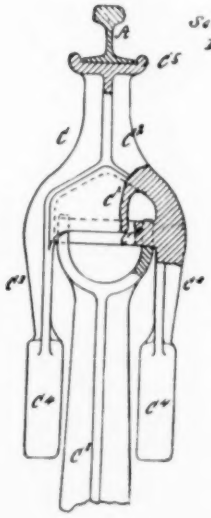
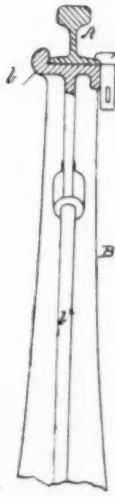


Fig 16



Section tt
Fig 18.

Fig 17



Section yy
Fig 18.

Hot-Bed (F.F' Fig 1)

Fig. 18.

Kolb-Bett. (Fig. 17, Fig. 18.)

AN ACCOUNT OF CERTAIN TESTS OF THE TRANSVERSE STRENGTH AND STIFFNESS OF LARGE SPRUCE BEAMS.

BY

GAETANO LANZA,

Professor of Applied Mechanics, Massachusetts Institute of Technology,

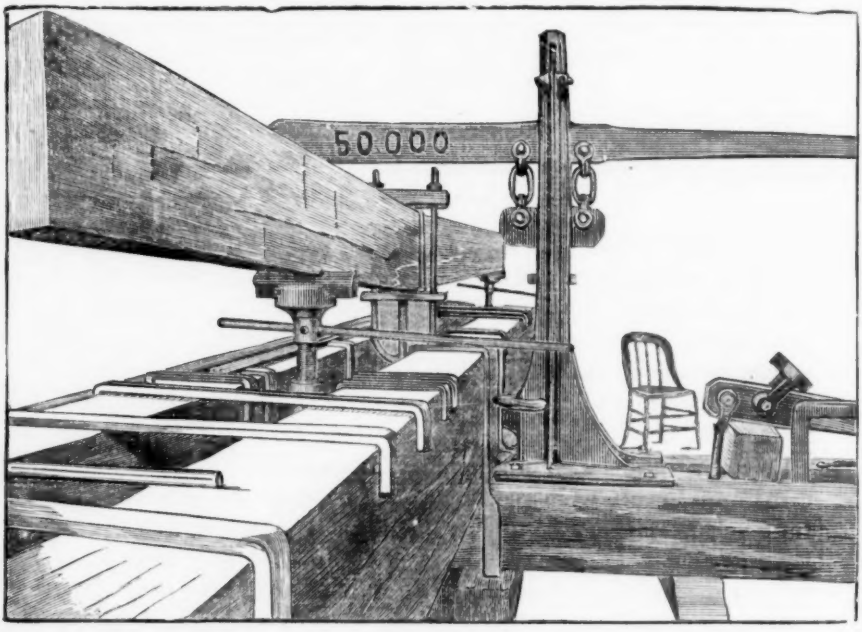
BOSTON, MASS.

I BEG leave to call your attention to the results of certain tests of the transverse strength and stiffness of full-size spruce beams, carried on by members of my classes in my laboratory at the Massachusetts Institute of Technology. The machine with which they were made is a 50,000-pound machine, and is capable of testing beams twenty-five feet long and under, as well as many of the framing joints used in practice.

It consists, as shown in the cut, of a compound lever, hung in a cast-iron frame, to which is connected, by means of a steel rod and turn buckle, one end of a lever, of equal arms, placed below, this lever having a 12-inch leverage, and being connected at its other end by means of a chain with the yoke shown in the cut. Two hard pine beams, each 20 inches deep, 10 inches wide, and 26 feet long, are laid across the timbers of the machine in such a way that the chain already referred to is midway between them. Two common jack-screws, each in a pair of wrought iron stirrups, are placed at a distance apart depending upon the span of the beam to be tested, the latter being placed, as shown in the cut, upon the jack-screws and under the yoke. The jack-screws are then screwed up, and the beam to be tested is thus raised at its two ends, and hence loaded at the point where the yoke is attached.

It was in operation about two months last session, and has been in operation about one month this present session. During that time we have tested about thirty specimens for breaking strength and about fifteen for deflection. The breaking has been effected as rapidly as could be done, consistently with the determination of the deflections, and the deflections under various loads were measured within a very short time after the application of the loads. In short, no experiments have thus far been carried on to determine the effect of time upon these quantities, though some will be made

very soon. It was also deemed best to keep to one kind of timber until we should have a sufficient number of tests to warrant us in drawing a conclusion as to the average value of the modulus of



rupture, and of the modulus of elasticity of that kind of wood; and spruce was selected, as a wood that is very much used in building. Experiments are now in progress in my laboratory to determine the same quantities for yellow pine.

The results that were obtained last session are shown above the double line in the accompanying table, and those obtained this present session, below.

At the beginning of this session these tests were continued, with the following objects in view:

1. Inasmuch as the lumber had, last session, been selected either by a carpenter, without reference to testing, or had been simply ordered at the yard, directions being given to the dealer to send merchantable stock, it seemed best that I should go the yards myself and select from the piles some of the best and some of the average of what was on sale as merchantable stock, and thus that we should be able to speak with certainty about the values of the modulus of rupture and modulus of elasticity of such lumber.

2. Inasmuch as last year we had had only three determinations of the modulus of elasticity, it was desirable to obtain more values, and thus to be able to determine an average value.

3. It was desirable to see how far, in the light of what had already been done, we should be able to judge of the modulus of rupture by simply inspecting a piece of timber, and to endeavor also to train the students, to some extent, to have this ability.

That the values of the modulus of rupture which we have obtained should differ very considerably from those given in our text-books and engineers' handbooks, and deduced from tests of small pieces, I need not tell a company of engineers; but, as you may not carry in your minds the precise figures given by different authorities for the modulus of the rupture of spruce, I will place them here:

Hatfield gives as mean value .	.	9,900 lbs.	per sq. in.
Rankine " " .	.	11,100	"
Laslètt " " .	.	9,045	"
Trautwine " " .	.	8,100	"
Rodman " " .	.	6,168	"

Trautwine advises for use to deduct one-third in the case of knotty and poor timber.

NO. OF TEST.	WIDTH AND DEPTH IN INCHES.	DISTANCE BETWEEN SUPPORTS. Ft.	In.	MANNER OF FIXING THE ENDS AND LOADING.	BREAKING WEIGHT IN POUNDS.	MODULUS OF RUPTURE IN LBS. PER SQ. IN.	MODULUS OF ELASTICITY IN LBS. PER SQ. IN.	REMARKS.
1	2 x 12	6	8	Framed at ends	6,304			
2	4 x 12	6	8	Header	10,338			
3	2 x 12	15		Load at middle	5,794	5,432	1,237,215	
4	2 x 9	6	7.5	" "	7,227	5,320	1,067,893	
5	2 x 12	15		" "	5,586	5,237		
5 (a)	2 x 12	7		" "	8,982			
6	2.75 x 9	6	8	" "	7,586	4,082	938,453	
7	3 x 9	4		" "	11,086	3,285		
8	3 x 9	10		" "	6,086	4,508		
9	3 x 9	15		" "	5,086	5,651		
10	$3\frac{7}{8}$ x 12	20		" "	6,586	4,253		
11	2.5 x 13.5	10		" "	9,585	3,787		
12	3.75 x 12	16		Load 4'.5 ft. from one support	7,585	3,271		
13	3.75 x 12	16		Ditto, mortised	9,085			
14	7 x 2	7		Load at middle	1,944	8,748		Selected stock.
15	1.75 x 6.75	7		" "	4,785	7,562		Selected stock.
16	3 x 9	6	8	" "	9,985	4,931		
17	3 x 9	6	8	Load at 4 points, 16 ins. apart	16,744	4,961		
18	3.9 x 12	16		Load 4'.5 ft. from one support	12,585	5,218		
19	2 x 12	14		Load at middle	4,404	3,854	1,482,645	
20	2 x 12	14		" "	5,108	4,469	1,588,548	
21	$3\frac{1}{16}$ x 12	14		" "	8,627	3,834	1,187,073	
22	$3\frac{7}{8}$ x 12	14		" "	12,545	5,666	1,332,715	
23	$3\frac{1}{2}$ x $12\frac{1}{4}$	14		" "	6,917	2,995	897,961	
24	3 x $11\frac{7}{8}$	14		" "	8,927	5,442	1,572,470	
25	2 x $9\frac{3}{4}$	14		" "	3,198	4,239	1,460,620	
26	$2\frac{3}{8}$ x 12	14		" "	6,819	4,339	1,396,667	
27	$1\frac{15}{16}$ x 10	14		" "	4,306	5,601	1,355,860	
28	$4\frac{1}{8}$ x 12	18		" "	8,829	4,816	1,397,136	
29	4 x $12\frac{1}{8}$	18		" "	8,324	4,586	1,259,224	
31	$3\frac{1}{8}$ x 12	18		" "	7,721	5,559	1,231,498	
						25)115,336	15)19,405,978	
						4,613 = Av. mod. of rupture.	1,293,732 = Av. mod. of elasticity.	

As a result of the tests thus far made in my laboratory, it seems to me safe to say, that if our Boston lumber yards are to be taken as a fair sample of the lumber yards in the case of spruce, that if such lumber is ordered from a dealer of good repute, no selection being made except to discard such pieces as might be classed as culled timber, *i. e.*, that which is rotten or has holes in it, that 3,000 pounds per square inch is all that could with any safety be used for modulus of rupture, and even this might err in some cases, in being too large. 2. That if the lumber is carefully selected at any one lumber yard, so as to take only the best of their stock, it would not be safe to use for modulus of rupture a number greater than 4,000, and if we required a lot of spruce lumber which should have a modulus of rupture of 5,000 it would be necessary to select a very few pieces from each lumber yard in the city.

Next, as to the modulus of elasticity: Until the beginning of this session we had made only three experiments on this subject, and these gave as an average 1,081,187; those made this autumn have contributed to raise this value somewhat, as will be seen from the table, where we obtain an average of 1,293,732.

Of course it is naturally to be expected that time tests will give much smaller values for both modulus of rupture and modulus of elasticity.

As to the variations of the values shown in the table, they are considerable, and depend upon the quality of the lumber, *i. e.*, upon the number and location of the knots, the shakes and cracks, that are so commonly found at the heart of timber, also upon the degree of seasoning, although it is my opinion that the increase of strength due to this latter item has often been overestimated. Knots near the middle of the span act very prejudicially, whether they are at the top or at the bottom, and by saying near the middle of the span I mean to include a very considerable range. It is impossible, however, to describe the mode of judging correctly, from inspecting a stick, what will be its modulus of rupture, and this ability can only be acquired by practice, and this very practice is one of the benefits that it is hoped to enable the students to gain to a greater or less degree.

As to the relation between the modulus of rupture and the modulus of elasticity, while it is generally true that those pieces that have a high value of the one have a high value of the other, and *vice versa*, nevertheless, I have not been able thus far to form any definite idea of the connection between them, at least such as to enable

one to attempt to predict the modulus of elasticity from the appearance of the piece. Perhaps further experiments may satisfy this want, and as to the desirability of satisfying it no one can have any question, for the stiffness of beams is, or ought to be, as prominent a question to builders as their breaking strength. .

We have already made three, and shall make quite a number of experiments on the strength of framing joints, such as headers, trimmers, etc., in regard to which we have thus far been entirely devoid of any experimental knowledge.

As to the method of fracture: While the most usual fractures in spruce beams have occurred either by tension or compression, or a combination of the two; nevertheless in some cases the beams have been split from the middle to one end, along or near the neutral axis; and while the experiments where this kind of fracture has occurred are not sufficient in number to warrant definite conclusions as yet, nevertheless it is an element that is forcing itself very strongly upon our attention as one that must be taken into account in practice.

A noticeable instance of this kind is to be found in the case of beam No. 22, another in beam No. 24, and a third in beam No. 31, which gave way in that manner.

[At the meeting a number of photographs of the fractures obtained were exhibited and commented upon.]

TABLE OF TESTS.

The following are the records of the tests made during the first month of the present session by students in the Department of Applied Mechanics of the Massachusetts Institute of Technology. In these tables, as far as the deflections are concerned, the first load is assumed as the starting point, the deflection under that load being counted zero.

The deflections are recorded to the 10,000th of an inch, as the measurements were made with a micrometer screw that could be read to that degree of accuracy, and hence it was thought best to give the results as they were obtained, although it is not claimed that change of temperature or other disturbing causes, which would be inappreciable as far as any practical result is concerned, may not cause so great a variation as to render it unnecessary to read to such a degree of accuracy.

The spruce, with the exception of Nos. 22 and 23, was cut in the spring of 1882, and brought from Bangor, Me. Nos. 22 and 23 were

cut in 1881. The students making the tests hand in the reports of the same, and make the necessary computations of modulus of rupture, modulus of elasticity, etc. The values given in the tables have been re-computed by my assistant, Mr. Edward F. Ely.

The number given as the "Max. intensity of shear at neutral axis" is that which would be obtained by computing it from the breaking load in accordance with the ordinary theory of beams.

No. 19.—Spruce Joist, 2 in. by 12 in. Span 14 feet. Loaded at center. Ordinary stock.

Tested by Messrs. Tompkins and Gustin.

Load in lbs	Deflection in inches.	Differences.	
485	.0000		
686	.0473	.0473	Rested over night.
510	.....	.....	Load on next morning.
485	.0000	.....	Began new set of readings.
686	.0343	.0343	
887	.0825	.0482	
1,088	.1284	.0459	
1,088	.1309	.....	After 1 hour.
1,289	.1764	.0455	
3,600	.....	.....	Cracks opened near center above neutral axis.
4,103	.....	.....	Bulging on east side at top. At center, top slewed to west.
4,404	.....	.....	Breaking load.

Fracture occurred within an hour after application of breaking load.

Line of fracture followed the knots.

Modulus of rupture = 3,854 lbs. per square inch.

Mean deflection for 201 lbs. = .0465.

Modulus of elasticity = 1,482,645 lbs. per square inch.

Maximum intensity of shear at neutral axis = 138 lbs. per square inch.

No. 20.—Spruce Joist, 2 in. by 12 in. Span 14 feet. Loaded at center. Not many knots.

Tested by Messrs. Tompkins and Gustin.

Load in lbs.	Deflection in inches.	Differences.	
485	.0000		
686	.0431	.0431	
887	.0885	.0454	
1,088	.1303	.0418	
5,813	.....	.....	Twisted badly in spite of bracing, and load fell off rapidly, it being impossible to keep this load on.
5,108	.....	.....	Breaking load.

Modulus of rupture = 4,469 lbs. per square inch.

Mean deflection for 201 lbs. = .0434.

Modulus of elasticity = 1,588,548 lbs. per square inch.

Maximum intensity of shear at neutral axis = 160 lbs. per square inch.

No. 21 Spruce Joist, $3\frac{1}{16}$ in. by 12 in. Span 14 feet. Loaded at center. Ordinary stock.

Tested by Messrs. Tompkins and Gustin.

Load in lbs.	Deflection in inches.	Differences.	
686	.0000		
1,088	.0546	.0546	
1,490	.1033	.0487	
1,892	.1654	.0621	
2,294	.2192	.0538	
2,696	.2858	.0666	
3,098	.3397	.0539	
3,500	.4030	.0633	
3,902	.4644	.0614	
4,304	.5256	.0612	
4,706	.5898	.0642	Left over night.
4,203	.5845	.....	Next morning.
4,706	.6529	.....	Load increased to 4,706 again.
4,404	.....	.....	Next day.
5,610	.....	.....	Braced the stick.
8,627	.....	.....	Breaking load after carrying 15 minutes.

Modulus of rupture = 3,834 lbs. per square inch.

Mean deflection for 402 lbs. = .0590.

Modulus of elasticity = 1,187,073 lbs. per square inch.

Maximum intensity of shear at neutral axis = 137 lbs. per sq. in.

No. 22.—SPRUCE JOIST, $3\frac{7}{8}$ in. by 12 in. Span 14 feet. Loaded at center. Lower part of tree. Very free from knots. Had been seasoning on the wharf about one year.

LOAD IN LBS.	DEFLECTION IN INCHES.	DIFFERENCES.	
485	.0000		
887	.0534	.0534	
1,289	.1052	.0518	
1,691	.1583	.0531	
2,495	.2665	.1082	
3,299	.3748	.1083	
4,103	.4810	.1062	
4,907	.....	.....	Left over night.
4,203	.....	.....	Next morning.
12,545	.....	.....	Breaking load. Beam broke by tension and afterward by shearing along the neutral axis. Shear extended from center to one end, and pieces slid by one another about $\frac{7}{16}$ inches.

Modulus of rupture = 5,666 lbs. per square inch.

Mean deflection for 402 lbs. = .0534.

Modulus of elasticity = 1,332,715 lbs. per square inch.

Maximum intensity of shear at neutral axis = 202 lbs. per sq. in.

No. 23.—SPRUCE JOIST, $3\frac{7}{8}$ in. by $12\frac{1}{4}$ in. Span 14 feet. Loaded at center. Upper part of same tree as No. 22. Very knotty. Had been seasoning on the wharf about one year.

Tested by Messrs. Tenney and Mansfield.

LOAD IN LBS.	DEFLECTION IN INCHES.	DIFFERENCES.	
485	.0000		
887	.0819	.0819	
1,289	.1457	.0638	
1,691	.2204	.0747	Left over night.
1,425	.....	.....	Next morning.
1,691	.2569	.....	Raised load again.
2,093	.3269	.0700	
2,495	.4017	.0748	
2,897	.4828	.0811	
3,299	.5536	.0708	
4,103	.7073	.1537	
4,907	.....	.....	Left on for half an hour, during which time load fell off to 4,202; beam splitting and cracking at a large knot on lower edge near center of span.
6,917	.....	.....	Breaking load (knot causing break about 15 inches from center).

Modulus of rupture = 2,995 lbs. per square inch.

Mean deflection for 402 lbs. = .0745.

Modulus of elasticity = 897,961 lbs. per square inch.

Maximum intensity of shear at neutral axis = 108 lbs. per. sq. in.

No. 24.—SPRUCE JOIST, width $3\frac{1}{16}$ in. at bottom, $2\frac{7}{8}$ in. at top, depth $11\frac{7}{8}$ in. Span 14 feet. Loaded at center. Not many knots.

Tested by Messrs. Scott and Foran.

LOAD IN LBS.	DEFLECTION IN INCHES.	DIFFERENCE.	
485	.0000		
887	.0603	.0603	
1,289	.1247	.0644	
1,691	.1835	.0588	
2,093	.2485	.0650	Left 15 hours, when load had fallen to 1,766 lbs.
2,093	.2742		
2,495	.3285	.0543	
2,897	.3870	.0585	
3,299	.4521	.0651	
3,701	.5189	.0668	
4,103	.5746	.0557	
8,927	.....	.....	Breaking load. Broke by shearing along neutral axis. Split open about 1½ inches.

Modulus of rupture = 5,442 lbs. per square inch.
Mean deflection for 402 lbs. = .0610.
Modulus of elasticity = 1,572,470 lbs. per square inch.
Maximum intensity of shear at neutral axis = 190 lbs. per sq. in.

No. 25.—SPRUCE JOIST, 2 in. by $9\frac{3}{4}$ in. Span 14 feet. Loaded at center. Ordinary stock.

Tested by Messrs. Scott and Foran.

LOAD IN LBS.	DEFLECTION IN INCHES.	DIFFERENCES.	
485	.0000		
887	.1625	.1625	
1,289	.3342	.1717	
1,691	.5280	.1938	
3,198	.....	.....	Breaking load, by compression at top and tension at bottom.

Modulus of rupture = 4,239 lbs. per square inch.
Mean deflection for 402 lbs. = 1,760.
Modulus of elasticity = 1,460,620 lbs. per square inch.
Maximum intensity of shear at neutral axis = 123 lbs. per sq. in.

No. 26.—SPRUCE JOIST, $2\frac{3}{4}$ in. by 12 in. Span 14 feet. Loaded at center. Ordinary stock.

Tested by Messrs. Tenney and Mansfield.

LOAD IN LBS.	DEFLECTION IN INCHES.	DIFFERENCES.	
485	.0000		
887	.0534	.0534	
1,691	.2050	.1516	
2,495	.3610	.1560	
3,299	.5025	.1415	
5,610	.....	.....	Cracked somewhat.
5,713	.....	.....	Cross-grained fiber at bottom tore apart.
5,914	.....	.....	A sharp crack was heard and a long split appeared.
6,819	.....	.....	Breaking load.

Modulus of rupture = 4,339.

Mean deflection for 402 lbs. = .0718.

Modulus of elasticity = 1,396,667 lbs. per square inch.

Maximum intensity of shear at neutral axis = 155 lbs. per square inch.

No. 27.—SPRUCE JOIST, $1\frac{15}{16}$ in. by 10 in. Span 14 feet. Loaded at center. Not many knots.

Tested by Messrs. Tenney and Mansfield.

LOAD IN LBS.	DEFLECTION IN INCHES.	DIFFERENCES.	
485	.0000		
887	.1724	.1724	
1,289	.3272	.1548	Beam tipped and braces were put in at ends beyond the straight edges.
1,691	.5441	.2169	Wedge was used on west side to keep straight edge close to the beam.
4,306	.....	.....	Breaking load.

Modulus of rupture = 5,601 lbs. per square inch.

Mean deflection for 402 lbs. = .1814.

Modulus of elasticity = 1,355,860 lbs. per square inch.

Maximum intensity of shear at neutral axis = 167 lbs. per sq. in.

No. 28.—Spruce Joist, width $4\frac{1}{4}$ in. at bottom, 4 in. at top, depth 12 in. Span 18 feet. Loaded at center.

Tested by Messrs. Tenney and Mansfield.

Load in lbs.	Deflection in inches.	Differences.	
485	.0000		
887	.1049	.1049	
1,691	.2999	.1950	
2,495	.5030	.2031	
3,299	.7033	.2003	
3,701	.8136	.1103	
4,103			
8,829	.....	.....	Breaking load.

Modulus of rupture = 4,816 lbs. per square inch.
Mean deflection for 402 lbs. = .1017.
Modulus of elasticity = 1,397,136 lbs. per square inch.
Maximum intensity of shear at neutral axis = 134 lbs. per sq. in.

No. 29.—Spruce Joist, 4 in. by $12\frac{1}{8}$ in. Span 18 feet. Loaded at center.

Tested by Messrs. Scott and Foran.

Load in lbs.	Deflection in inches.	Differences.	
485	.0000		
887	.1048	.1048	
1,289	.2169	.1121	
1,691	.3267	.1098	
2,093	.4424	.1157	
2,495	.5488	.1064	
2,696	.6227	.0739	
2,897	.6768	.0541	
6,917	.....	.....	Slight cracks heard.
8,324	.....	.....	Breaking load.

Modulus of rupture = 4,586 lbs. per square inch.
Mean deflection for 402 lbs. = .1128.
Modulus of elasticity = 1,259,224 lbs. per square inch.
Maximum intensity of shear at neutral axis = 129 lbs. per sq. in

No. 31.—Spruce Joist, $3\frac{1}{8}$ in. by 12 in. Span 18 feet. Loaded at center.

Tested by Messrs. Davis and Morse.

Load in lbs.	Deflection in inches.	Differences.	
845	.0000		
887	.1486	.1486	
1,289	.3030	.1544	
1,691	.4514	.1484	
2,093	.6129	.1615	
2,495	.7615	.1486	
3,701	.....	.....	Cracking commenced.
7,721	.....	.....	Breaking load. Broke suddenly by compression of top fibers and shearing along the neutral axis. Split showed several small pin knots, running vertically in the beam, and apparently pinning the sides of the fracture together.

Modulus of rupture = 5,559 lbs. per square inch.

Mean deflection for 402 lbs. = .1523.

Modulus of elasticity = 1,231,498 lbs. per square inch.

Maximum intensity of shear at neutral axis = 154 lbs. per square inch.

DISCUSSION.

Mr. Partridge.—I would like to ask Professor Lanza whether he has made anything more than judgments of the quality of the timber by the eye—whether he has made any microscopic examinations or attempted to carry his work further than the unassisted eye would carry it.

Professor Lanza.—I have not, Mr. President. Mr. Partridge's question gives me an opportunity to say something I would not wish to state in the paper formally. That is, that I amused myself by guessing—and the students have done the same thing to some extent—at what the pieces broken this year would bear, judging simply by the eye. I will give an idea of some of those pieces. Take the first one, No. 19, I think the guess was 4,575; the break-

ing weight is 4,404. For the second one, I think, our guess was 5,500; the breaking weight is 5,815. On No. 22, the guess was 12,000, which shows that the general appearance of the timber will enable us to approximate its breaking strength. It broke at 12,500.

Mr. Partridge.—I have had some little experience in what might be called the investigation of the character of a piece of timber microscopically. As most mechanics here know, perhaps one of the earliest uses of the microscope was in the investigation of the character of different woods. The first specimens that I mounted opened the structure of a piece of wood so that you could characterize it with almost the distinctness with which we characterize a piece of brickwork. We know whether it is fine brickwork or brickwork of the commonest kind. We know whether the joints are half-inch or as thin as they can be got. So in a piece of timber, nature's building becomes very plain under a power of perhaps 150, 200 or 300 diameters, just as may be convenient. The cells open themselves out. The character of those cells, whether they are well united to each other or far apart, the relationship of the sap pores to the general mass of the timber and the character of the binding—that is, the medullary rays—become very clear; so that I think by micrometric measurements of the photographs—for I would not attempt any work of this kind without photographing every specimen to go under the microscope—that it would be easy to know the reasons for a great many things which at the present time are obscure. I presume if the Professor should mount sections from those timbers which break in so peculiar a way, that he would find characteristics of structure visible which would account for that particular manner of breakage. And I have found, certainly, in yellow pine, cases where the structure exhibited so marked a difference in a good piece of timber and a poor piece, that one would have no hesitation in assigning the cause of breakage. Unfortunately my photographs and negatives are in Philadelphia. They were recently exhibited there by Dr. Grimshaw. If they were here, I could make use of the lantern and show definitely what I mean. Not long ago a bridge was erected near this city in which two **A** frames carried the load of a draw. The **A** frames, owing to the diminished size of the bearing casting, overhung the casting on which the draw rested by about 12 inches. The timbers themselves were two 12-inch timbers, one above the other. When an empty truck was passing, the **A** frames gave way, and the foot of one of the frames was pulled down through

that 24 inches of timber, shearing it off almost like a knife. Pieces came out nearly egg-shaped. One of those was given me, and on mounting the section for the microscope, I found that it was not unlike the appearance of a brick wall where there is more mortar than brick. The cells were long, large, continuous and very slightly joining, and the medullary rays, when a section parallel to the bark was taken, appeared only at long intervals.

A good piece of pine showed the medullary rays scattered up and down so thickly that instead of having vertical lines with here and there a bunch on them, you had a series of small bubbles, as it were, strung along the line representing the vertical fiber. Such differences as that were so marked and in connection with tests of strength would give such clear indications, that it seems to me very unfortunate not to have the microscopic work hand in hand with the testing. It is, I think, to timber what chemical analysis is to the testing of metals.

Professor Egleston.—I regret that I did not hear the paper, nor more than the last sentence of the discussion. I had occasion some years ago to draw up the programme of a report for the United States engineers with regard to the testing of metals used in the fortifications of the United States. I have had occasion once or twice in the engineering societies to allude to this fact, and have often had cause to regret, in making researches in my laboratory on metals, as I regret now in public, that no report of these experiments was ever made, and no report of the subsequent investigations exists except, perhaps, in manuscript in some pigeon-hole in Washington. In making the report to the Board of Engineers I told them then that any experiments that were made in testing metals would hardly be a fair exhibit of those tests unless a microscopic examination accompanied them. In one of the last numbers of "Eisen und Stahl," perhaps the best publication on iron and steel that is being issued in Europe at the present time, I find a long article insisting upon microscopic examinations accompanying the tests of metals. They refer there particularly to iron and steel. In the course of my professional experience, in the last eighteen months I have had occasion to use the microscope a great deal in this way, and I have recently determined that the next expenditure that I have occasion to make on such investigations, must be made in the direction of specially adapting a microscope for the study of tests of metals. I do not think there is a more important branch of testing than this kind of examination. There is a change, which

may require several hundred examinations to be made before many conclusions can be drawn, which goes on in every metal or alloy that I have ever examined, which is often made visible to the eye in the course of the commencement of the fracture, and afterward in the fracture itself, but which can only be completely studied under the microscope. But I think it is evident to any one who would make any examination of the subject at all that there is here a method of investigation which, although it cannot be said to be entirely new, may give as valuable, or even more valuable, results as the testing machine itself. I believe that similar changes may be detected in woods, and I therefore feel the greatest interest in any new investigation of structural materials.

Professor Lanza.—I fully believe in the value of the suggestions made. There are, however, several other points that ought to be investigated, one of which is the action of time upon the breaking weight. The first beam that was tested last year was a 2 x 12. I have forgotten the span, but I remember that the load was brought to about 5,800 pounds. It had to be left over night. The load dropped off, as it will, of course, in any screw machine, to about 3,000, and the next day it broke at 3,500. It had been under load over night. I have no doubt at all that the modulus of rupture will be very much lowered from those figures as soon as the action of time is taken into account. So also will be the modulus of elasticity, especially in wood. The deflection keeps increasing for a long time. The object of the tests has been to enable us to say with some degree of certainty, when we have a piece of timber to use, what will be approximately its breaking weight and what its modulus of elasticity. Then we can see what effect a time test will have, whether half its breaking weight or a quarter, or what part of its breaking weight will break it in the course of time. But, until we had some such data with which to start, it seemed almost useless to experiment on any more recondite matters.

Mr. Charles E. Emery.—I will take but a moment on this subject. It seems difficult to understand at once why a beam, flexed when the load is applied at the top, should divide only at the neutral axis. It is, however, in keeping with what I may call a theory advanced in a paper written about two years ago by myself in explanation of the high results given by beams as compared with those worked out by the usual formula. It will be recollected by those who saw the paper, though probably not many here present did, that the explanation was based on the calculated position of the

isodynamic curves in the longitudinal section of a beam. They curve from both upper and lower edges of the beam at either side of the load through the central section, and out again the other side. If we consider, as is usual, that at the neutral axis there is no motion, and at the outside maximum motion, my theory only requires that the beam bend a little at each side of the load, where, the strain being less, there could be an additional strain thrown on the fibers near the neutral axis along the general line of the corresponding isodynamic curve. If this be true, it seems very probable that there is a whole bundle of fibers, above the n utral axis, pulling with a greater intensity toward the axis *than is due to their position*, so that there is a shearing force, longitudinally, tending to produce rupture at the axis; and the additional strains on fibers near the axis relieve the outer fibers, thus accounting for the discrepancies between the practical results and those shown by the usual formula. As a matter of course, we can see why there is a tendency to produce shearing when the load is applied to the bottom of the beam, but this explanation applies when the load is applied either to the top or bottom.

Professor Lanza.—I should like to say that the formula from the ordinary theory of beams for the intensity of the shearing force at the neutral axis is in the case of rectangular beams very simple, especially in the case of a rectangular beam loaded at the middle. It is simply the supporting force divided by two-thirds of the area of the cross-section. That gives for that best beam, No. 22 (referring to the table), a shearing force of 202 pounds to the square inch at that neutral layer. The other beam that broke in that way gave 190. Those shearing forces are below the shearing forces that were determined at the Watertown Arsenal for the shearing strength of spruce. Nevertheless, of course the shearing of the beam occurs at the weakest part. But I have not yet seen enough consecutive evidence in the experiments figured up to enable me to make a connected theory.

ADJUSTABLE CUT-OFF FOR MARINE ENGINES.

BY

H. S. HAYWARD, JERSEY CITY, N. J.

As a practical engineer on ocean steamers, I have experienced a great deal of economy, especially where we have had a limited coal supply, in the judicious use of an adjustable cut-off. There are times when the engineers can avail themselves of favorable winds and smooth seas, and at other times they require all the power that their engines will develop.

In my railroad experience I find that a great deal of economy has also been realized on our locomotives by encouraging engineers to carry their steam up to the highest point allowed them, and cutting off their engines shorter instead of using the throttle.

FIG 2.

That, however, is a different case from the one we have under consideration, but it still demonstrates that engineers, whether on land or sea, can economize by cutting off shorter on the stroke of the engine instead of throttling the steam as it enters the cylinder.

Now, the advantage that we get by the use of the adjustable cut-off on the ferry-boats is on our long run up-town where we go up with the tide and come down against it, or *vice versa*.

These ferry-boats are required to make schedule time in order to connect with the trains; and to work our boats efficiently, I have adopted this system of a simple adjustable cut-off.

This cut-off attachment consists of a light rod running between the two steam-lifters, and on each end of the rod are plates with a rectangular slot, as shown in Fig. 2, at *ff*.

The upper and lower steam-lifting arms contain the mechanism for dropping the valves.

This consists of a plain bolt operated by a yoke and cam movement, as shown in Fig. 3.

These arms are cored in casting so that all they require in fit-

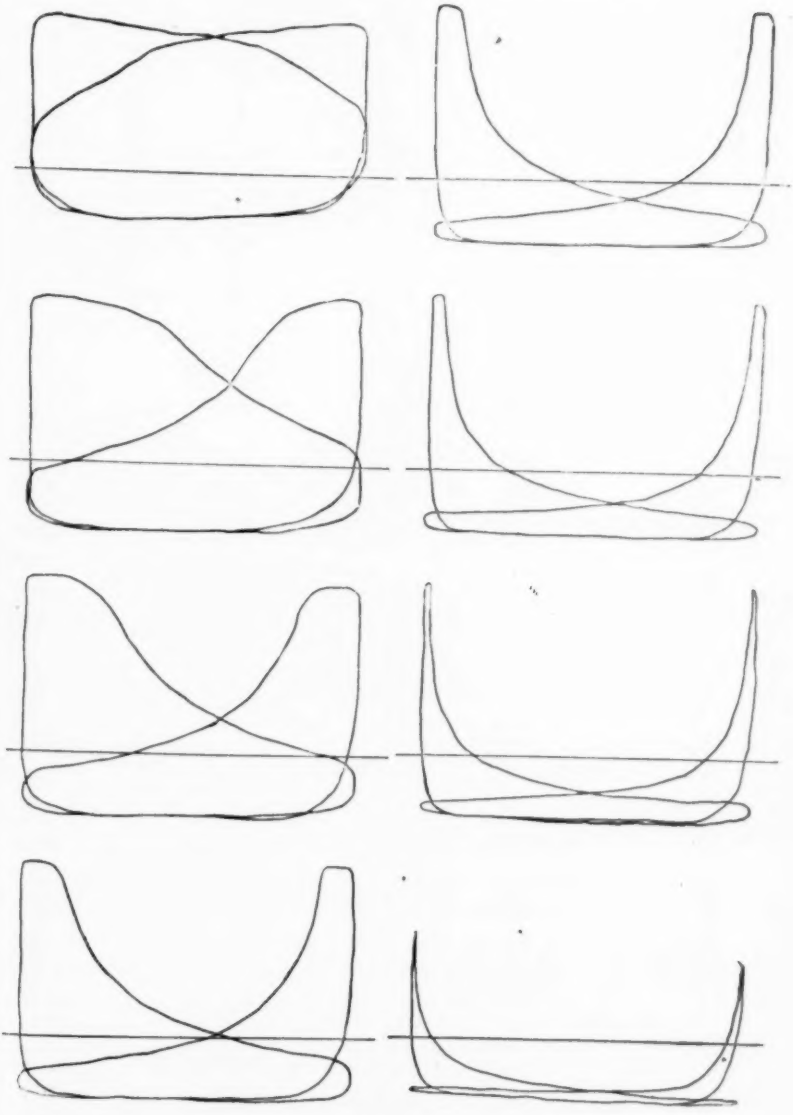


FIG. 3.

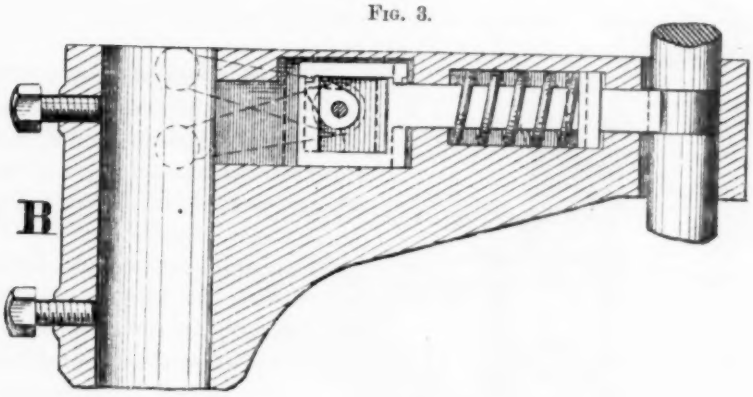
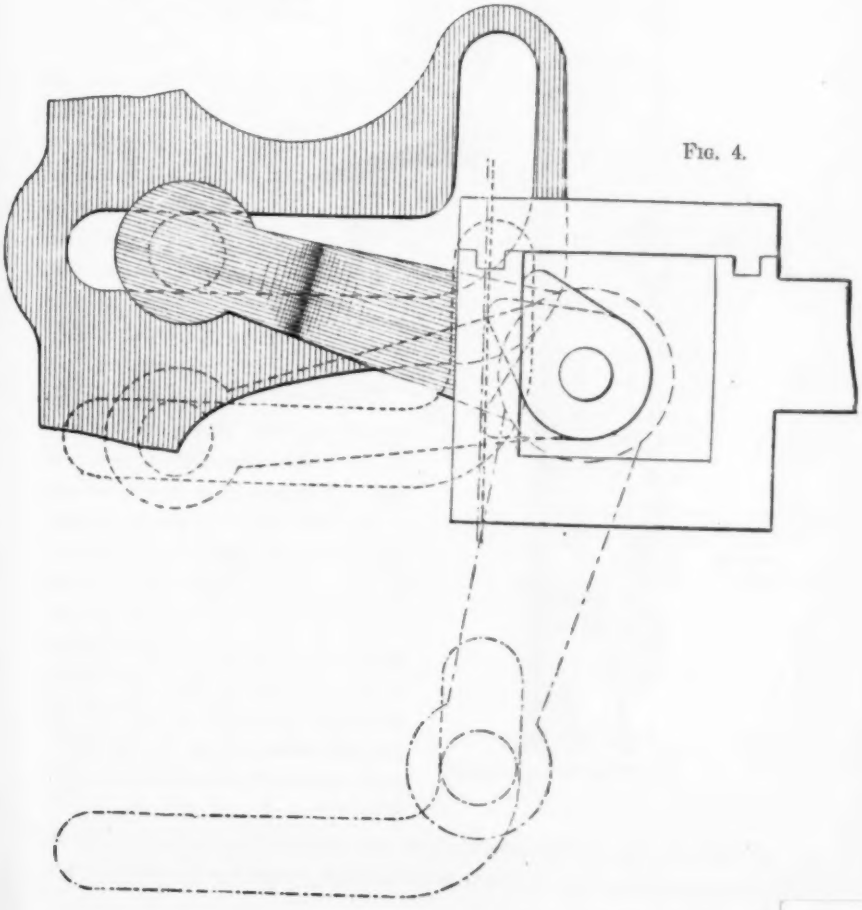


FIG. 4.



ting the bolts is a straight cut through them, and the fitting of the top plate.

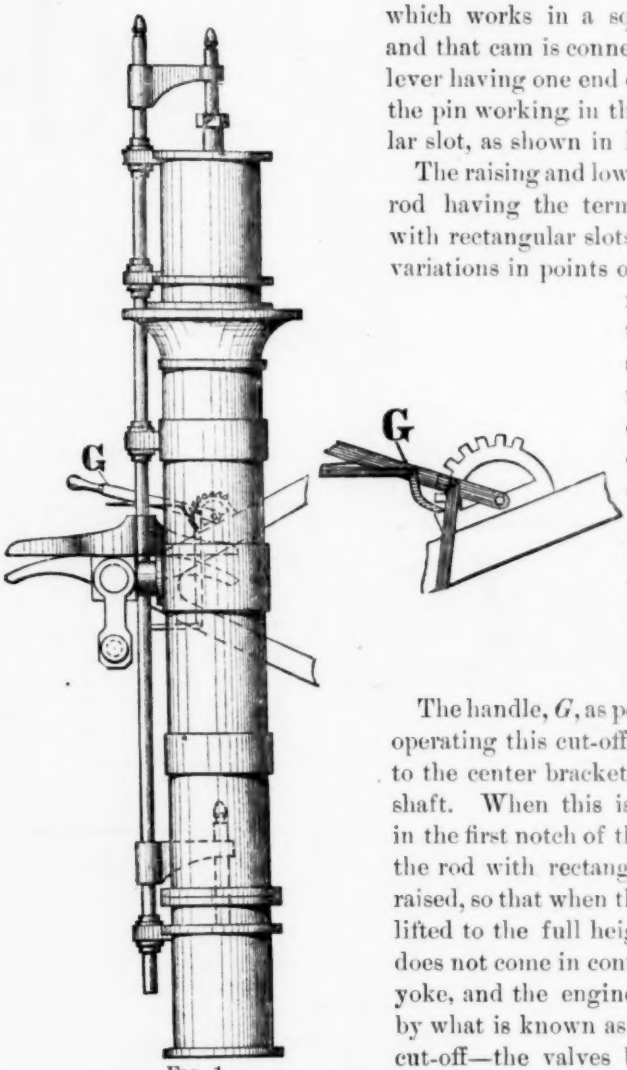


FIG. 1.

The bolt is operated by a cam which works in a square yoke, and that cam is connected with a lever having one end operated by the pin working in the rectangular slot, as shown in Fig. 4.

The raising and lowering of the rod having the terminal plates with rectangular slots causes the variations in points of cut-off by releasing the valve-stem from the brackets on the lifter rods at different points, as shown by the accompanying indicator cards.

The handle, *G*, as per Fig. 1, for operating this cut-off, is attached to the center bracket of the rock shaft. When this is thrown up in the first notch of the quadrant, the rod with rectangular slots is raised, so that when the valves are lifted to the full height the cam does not come in contact with the yoke, and the engine is working by what is known as the Stevens cut-off—the valves being raised and lowered by the steam toes and wipers.

With the use of this attachment you will notice, according to the indicator cards, that we have a very wide scope for variations.

If we have a valve set to close at three-quarters of the stroke, we can vary the point of cut-off down to a few inches on the length of stroke, or throw the steam valve stems entirely out of gear, allowing the engine to work on the vacuum.

I do not think that any further description is necessary; but I should be very much pleased if any members taking an interest in this subject should avail themselves of the opportunity when they are crossing to Jersey City, to examine the new ferry-boat "Baltimore," where it is now in operation.

I also beg leave to call your attention to a simple form of dash-pot which is used in connection with this cut-off (Fig. 5).

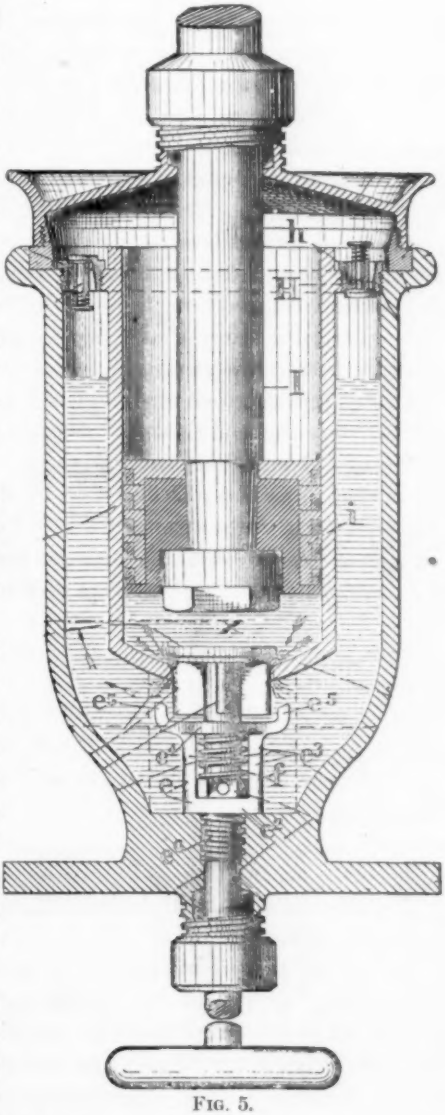


FIG. 5.

This dash-pot consists of two chambers—the inner one being made of brass, allowing a space between the outer and inner chambers little more than equal to the capacity of the inner one—the opening between the two chambers being made in the bottom of the inner brass chamber.

The main valve stem passing through the bottom of the steam chest, is carried down a sufficient length according to the location of the dash-pot, and is fitted with a solid plunger, with cast-iron packing-rings which work up and down in the inner brass chamber of

the dash-pot as per sketch. When the main steam valve of the engine is raised, since the lower end of the valve stem is connected with this plunger, it is also raised, and that produces a vacuum in the lower part of the inner dash-pot chamber. The valve, *a*, between the outer and inner chamber, is raised by the vacuum thus produced, and by the flow of oil from the outer to the inner chamber.

This valve is to a certain extent self-operating, on account of the compression of the spring working in the yoke connected with a regulating valve stem in bottom of dash-pot.

This regulating valve stem is used in adjusting the minimum opening of the foot-valve, so that on the return of the plunger, when the main valve is dropped, there is increased resistance to the passage of the oil on its return to the outer chamber on account of the partial closing of the valve. It is held but a short distance from its seat by the regulating valve stem.

There are also relief valves placed at the upper part of the dash-pot between the inner and outer chambers, as shown on sketch.

These prevent the main valve from being held from its seat on account of there being an excess of oil in the outer chamber, and the ingress valves are so arranged that if there should be any excessive leakage of oil through the plunger packing, the oil on the top of the plunger would be allowed to flow back into the outer chamber, and not cause an undue strain on the top cover of the dash-pot.

This practically makes it as nearly as possible a self-regulating dash-pot.

In order to seat the main valves slowly or rapidly, it is only requisite to increase or decrease the fixed amount of opening of the cataract valve between the two chambers, which is done by the regulating valve stem.

DISCUSSION.

The President.—I think Mr. Hayward has been making some experiments on that boat?

Mr. Hayward.—I have not been making any experiments. We are running her at present on what engineers term the third notch; that is but two notches below the point at which the valves are set. We still have two notches to go on for bad weather and ice in the river. That is a very important point, especially on the longer routes.

The President.—Haven't you been using that engine at very small points of cut-off, and very high rates of expansion?

Mr. Hayward.—The cut-off is so adjusted that you can use it in the place of a throttle. The engineer can slow down coming into the slip, and when he unhooks her, he throws the lever up, the same as he would upon his throttle, and then he is prepared to work his engine by hand.

The President.—How does your wheel behave on a short cut-off?

Mr. Hayward.—We turn a very even wheel. But in connection with this I would state that we have constructed the outer ring of our wheel very much thicker than heretofore, and the boat is more free from the vibrations which you find on ferry-boats.

Mr. Holloway.—I would like to ask the gentleman whether it is the practice to cut off on the descending or ascending stroke?

Mr. Hayward.—The descending.

Mr. Holloway.—How do you manage to cut off at half-stroke?

Mr. Hayward.—You have to have your engine set for a very high lift, and to follow the greater portion of your stroke, so that you have from that point to any point under left to cut off at. They all have to cut off on the lift.

Mr. Holloway.—I think it is an excellent thing, but it is very similar to what has been used on the Lakes for several years.

Mr. Hayward.—All I look at in this is its simplicity and economy of construction.

THE PROTECTIVE VALUE OF BOILER INSPECTION.

BY

F. B. ALLEN, HARTFORD, CONN.

FROM a paper read by Mr. E. B. Martin, before the Institution of Mechanical Engineers at Manchester, England, in 1866, we learn that a very disastrous boiler explosion occurred in London in the year 1815. That explosion and others that occurred subsequently were made the subject of an inquiry by a Parliamentary Committee in 1817, who recommended, among other things, "that boilers should be made of wrought iron instead of cast iron or copper, which had been the materials mainly used previously; that they should be inspected and tested; and that there should be two safety-valves, each loaded to one-third of the test pressure under penalties for any excess."

Until 1830, boilers were rarely worked above ten pounds per square inch; indeed, seven pounds was the ordinary pressure. After that period the principle of working high-pressure steam expansively came into use; the pressures were increased to thirty and forty pounds per square inch, without increasing the strength of the weak forms of boilers then used, and in consequence many violent boiler explosions occurred, directing public attention to the subject, and the necessity for a better system of protection from the occurrence of these sad disasters. Sir William Fairbairn, who had for some years previously interested himself in this matter of boiler explosions, rendered invaluable service to the authorities where inquests were held (indeed, Sir William seems to have been the pioneer of the much-abused mechanical expert of our day), and organized in the city of Manchester an association of manufacturers and mill-owners for the protection of the lives and property of those who were exposed to the dangers of boiler explosions. The association established a system of periodical examinations and inspections, and employed skillful inspectors to have supervision over all boilers operated by its members. The plan worked admirably, not only in the prevention of boiler explosions, but the advice and recommendations made by its inspectors effected an increased

economy in the generation of steam, with greater durability of the boilers.

This association has since attained a world-wide celebrity, and the contributions of its present Chief Engineer, Mr. Lavington E. Fletcher, in the department of boiler engineering, have been important and valuable.

In a communication by the writer to the AMERICAN MACHINIST, November, 1878, comparing the protective value of the Government test of steamboat boilers under the direction of the board of United States Supervising Inspectors, with that of a more thorough and systematic examination by a boiler inspection and insurance company, compiled from official records in both cases and extending over a period of six years, it was shown that the cost in losses by explosion for each boiler inspected by the Government was $13.76, while that of the insurance inspection cost per boiler in losses paid $1.18. It will be apparent that the loss reported by the boiler insurance company was only that for which they were liable, and did not represent the entire loss in cases where the amount insured was less than the real value of the property. Assuming that the insurance policy covered but 25 per cent. of the total loss—and this assumption is undoubtedly greatly in excess of the actual amount—we have the cost in losses per boiler, inspected by the insurance company, at $4.72. Expressed in protective efficiency, the U. S. inspection was to that of the insurance inspection as .343 to 1. In comparing the advantages and disadvantages of the two systems, it will be conceded that the insurance inspection was chiefly that of stationary boilers, whose surroundings are ordinarily superior to those of a marine boiler, while in construction and attendance they are inferior to it.

Mr. Henry Hillier, Chief Engineer of the National Boiler Insurance Co., of England, testified before the "Parliamentary Select Committee on Steam Boiler Explosions," London, 1870:

"The explosions reported to me during the five years ending 31st Dec., 1869, were 288; of these I have obtained reliable particulars of 223, due to the following causes:

"*First.*—80, or 36 per cent., due to defects of construction, either of material or workmanship.

"*Second.*—87, or 39 per cent., due to defects arising during ordinary use of the boilers, such as corrosion, fractures, and grooving.

"*Third.*—56, or 25 per cent., due to actual neglect of attendants, as deficiency of water and, in most cases, over-pressure.

"Particulars of the remaining 65 explosions were not obtained."

Seventy-five per cent. of the defects enumerated above, comprising the first and second predisposing causes of explosion, are those which it is the special province of boiler inspection to discover, either at the first or subsequent examinations; while the system of quarterly visits of inspection made to the boilers while under steam in ordinary use, to examine safety-valves, steam-gauges, and other safety appliances, with its attendant supervision over those in charge of the boilers at the time of the inspector's visit, reduces to a minimum the danger to be apprehended from the third, or remaining cause.

I quote from the annual report of the inspection department of the Hartford Steam Boiler Inspection and Insurance Co., as follows:

Summary of the Inspectors' Report for the Year 1881.

During the year 1881, there were made 22,412 visits of inspection, being an increase of 1,473 over the number made in 1880; the number of boilers inspected was 47,245, an increase of 2,079 over the number inspected the previous year, while the number of complete internal inspections foots up 17,590, an increase of 1,580 over the number made in 1880. The hydrostatic test was applied in 4,286 cases, the majority of which were new boilers. This is an increase of 796 over the business of the preceding year.

The total number of defects found which were considered serious enough to be reported was 21,110, of which number 5,801 were of a dangerous nature. This does not include many defects of a less serious character.

The following table shows the defects in detail:

Nature of Defects.	Whole No.	Dangerous.
Furnaces out of shape	1,164	301
Fractures	2,417	1,414
Burned plates	1,180	426
Blistered plates	3,260	468
Cases of deposit of sediment	2,752	532
Cases of incrustation and scale	4,082	494
Cases of external corrosion	1,346	450
Cases of internal corrosion	899	266
Cases of internal grooving	225	128
Water-gauges defective	401	157
Blow-out defective	255	132
	17,981	4,768

Nature of Defects.	Whole No.	Dangerous.
Defects brought forward	17,981	4,768
Safety-valves overloaded	296	169
Pressure-gauges defective	1,647	375
Boilers without gauges	552	51
Cases of deficiency of water	128	101
Braces and stays broken	478	313
Seams leaking	8	3
Defective heads	13	13
Loose tubes	4	
Mud-drums defective	3	3
Dangerous defects unclassified		5
Total defects	21,110	5,801
Boilers condemned		363
Heads condemned		13
Mud-drums condemned		3

We would call attention to the above record of defects discovered, and then most respectfully ask: Is not the periodical inspection of steam boilers of some slight value? There can be but one answer to the above question, and that must be in the affirmative. It is impossible that a system of inspection which brings to light a total of nearly *six thousand* dangerous defects in one year, can fail of accomplishing an incalculable service to the steam-users of this country.—(*The Locomotive*, N. S., Vol. 3, No. 2.)

Many of the improvements in the construction and material of shell boilers in this country, during the past fifteen years, are due to boiler inspection and its demands for better work, in accordance with the requirements of its standard. A brief review of the principal or more important of these improvements may not be inappropriate in this paper.

Most of us remember the stationary steam boiler of twenty years ago, where the aim of the boiler-maker was to place as many small tubes in the boiler as it was possible to do, the value of circulation not being understood or appreciated. Contrast this with the tubular boiler of to-day, with its tubes set in vertical rows, no tube approaching nearer than three inches to the shell, with a clear opening down the middle of from two to six inches, according to circumstances, for a solid body of water, giving better circulation, affording better facilities for cleaning the boiler, as well as for making repairs to the fire sheets when required.

All shops were provided at that time with those mysterious tools known as drift pins, although no boiler-maker ever countenanced

their use. As an indication of progress, we may congratulate ourselves that evidences of their use are not nearly so common as they were a few years ago.

The advent of machine riveting required a more careful system of laying out and punching rivet holes, to insure satisfactory work in the completed boiler, the drawing of a rivet-head in any required direction, to cover an irregular-shaped hole, being much easier of accomplishment by hand riveting than with the machine. In the matter of calking riveted joints there has been a marked improvement over the carelessness that formerly prevailed under the old method, with the certainty of its breaking the skin of the iron in the under plate. It is wonderful how tenaciously many of our boiler-makers yet cling to that old relic of barbarism, the plane-faced calking tool.

The common practice in boiler construction, until recently, was to cut out the shell of the boiler the full size of the dome opening. Many serious explosions have been traced to weaknesses of that kind. In some other cases the appearance of leaks around the base of the dome, that continued to leak after repeated calking, led to an investigation of the cause, and a relief by bracing which prevented the distortion of the weak part around the dome flange. Occasionally new boilers are found defective in this important particular.

The problem of properly supporting long boilers, that, so far as practicable, there may be an even distribution of the load, is one in which there has been some diversity of opinion among engineers and boiler constructors, as to the best location of the supports to accomplish the object. The need of graduated supports on a boiler thirty feet long ought to be apparent to every one, yet inspectors often find boilers of this description with their whole weight resting on their extreme ends (front and rear), the effect of which is to throw an undue strain on the middle girth seams, which, if not discovered in time, and remedied, will cause a seam rip and the projection of the halves of the boiler in opposite directions, with a terrible destruction. The violent explosion at the Allentown Rolling Mill, in January, 1881, by which 13 persons lost their lives, was caused by a defect of this kind. It was estimated in that case that the weight of the boiler structure and its contained water was about 12,000 pounds.

In boiler fittings, the regulations of the United States Steamboat Inspection Service, as well as the inspection and insurance com-

panies at home and abroad, require a proper safety-valve for each boiler. In stationary boilers it should be attached by a nozzle, or some such suitable connection, directly to the shell of the boiler, without intervening stop-valves.

The practice of having but one safety-valve for a battery of from two to five boilers is a murderous one, which has been the cause of some of the most disastrous explosions known in this country. This matter deserves the attention of the authorities, and laws should be enacted in the different States, making the further use of boilers connected in this manner unlawful, and punishable by suitable penalties. In closing this retrospect, special credit is due Mr. J. M. Allen, President of the Hartford Steam Boiler Inspection and Insurance Company, for important investigations and the dissemination of much useful information, notably upon the subjects of the "Holding Power of Boiler Tubes," "Strongest Forms of Riveted Joints," and "Plan for Supporting Long Boilers in Iron Works."

The plan of condemning steam boilers after a prescribed term of years has been advocated, but apparently finds little favor with either engineers, boiler-makers, or boiler-users. All agree there is a time when a boiler reaches the limits of its usefulness, and should be relegated to the scrap heap; viz., when its condition indicates that it requires that treatment.

The practice of casting away passenger-car axles after a certain mileage, no matter what their apparent condition may be, is now generally adopted by our leading railway managers. This has been cited as one worthy of imitation in limiting the life of a boiler. Desirous of learning the practice of the Pennsylvania Railroad, and whether they had abandoned the one commonly used by engineers of determining the question of condition by an inspection, substituting in its stead the uncertain limitation of age irrespective of condition, I wrote for information to a gentleman who holds a responsible position in its machinery department. He replied as follows: "* * * Now, in regard to the life of a boiler, we do not pretend to place any limit upon their age; all depends upon their general condition, knowledge of which is obtained from weekly inspections or examinations of stay-bolts and fire-box sheets, and internal examination at intervals. So you see we are mortal like yourselves, and depend upon good material, mechanical skill in construction, and watchful care after they have been put in service for prolonging the existence of boilers."

The protective value of boiler inspection is further demonstrated by the following statement of the Manchester Steam Users' Association: "During the past fourteen years the Association has issued upward of 30,000 boiler guarantees, and not a single person has been killed or injured by any guaranteed boiler."—(*Engineering*, Vol. 27, p. 258.)

It is understood that the guarantees of this Association are issued only on selected boilers, located within a comparatively small territory, thereby enabling its inspectors to have constant supervision over them. These conditions do not exist in this country, except in our large cities. The Metropolitan district of the Hartford Steam Boiler Insurance Company comprises the cities of New York, Brooklyn, and Jersey City; in this district from 1866 to 1882, covering a period of sixteen years, but one explosion has occurred from which death or injury resulted.

During the year 1881, the company issued policies on some 15,000 boilers throughout the country, but two of which exploded. When the fact is taken into consideration that many of its policies are on boilers in sparsely settled parts of the country, run without skilled attendance, in many cases using bad water, and subject to many other unfavorable conditions, this showing is indeed remarkable testimony for the protective value of boiler inspection.

The proud record of the Manchester Company, the pioneer inspection company of the world, is undoubtedly due, among other causes, to the hearty co-operation of its members in the work of periodical inspection, and a prompt acquiescence in its recommendations. The importance of the subject of boiler inspection in its relation to the protection of human life appeals to every steam-user in the land to obtain the most thorough system of inspection offered, and to make suitable arrangements for periodical examinations.

Boilers should be permitted to remain long enough out of service to cool properly, and permit a thorough examination of their setting and fitting. It is now no uncommon occurrence for an inspector to have his shoes destroyed by hot cinders and ashes, or his flesh burned in an endeavor to make an examination of boilers and settings which he has been notified are ready for inspection. Such an inspection can be one only in name, and, obviously that kind of co-operation on the part of the steam-user in preparing for his inspection is not the kind advocated in this paper, nor will it afford the full measure of protection here contemplated.

The greatest need of the boiler inspection service in this country to-day is hearty and intelligent co-operation on the part of the steam-user, by which its efficiency may be further increased.

DISCUSSION.

Mr. Le Van.—I would like to ask Mr. Allen if I understood him to say it was proper to cut out the full size of the drum from the boiler shell?

Mr. Allen.—It is not proper.

Mr. Le Van.—Of what benefit is the remaining part of the boiler covered by the dome?

Mr. Allen.—It gives increased strength by imparting stiffness to the structure. The plan that I have advocated for boiler domes has been to place the manhole plate on the shell of the boiler. The statement made in my paper has special reference to boilers having the manhole on the top of the dome. The better plan would be to place the manhole on the shell of the boiler, and where a dome is used, to perforate only the plate.

Mr. Le Van.—What does the gentleman gain by that? It is nothing more than a bent stay.

Mr. Allen.—There is a certain stiffness gained. I do not mean to contend that the difference is very great, but the practice of cutting out a large amount equal to the full size of the dome is reprehensible.

Mr. Le Van.—Does not the gentleman know that the pressure is the same on each side?

Mr. Allen.—Yes, sir.

Mr. Le Van.—Then how can it be of any strength to the boiler?

Mr. Allen.—By imparting a stiffness which is necessary to prevent distortion.

BACK PRESSURE ON VALVES:

OR, THE EQUILIBRIUM LINE BY EXPERIMENT AND THEORY FOR BROAD-SEATED VALVES.

BY

S. W. ROBINSON,

Professor of Mechanical Engineering, Ohio State University.

THE title of this paper perhaps poorly indicates its true import. More specifically, an attempt is made to determine by experiment what fractional part of that pressure exerted upon the top surface of a valve by a fluid is required, when acting from below, to raise that valve from its seat. The valve is supposed to have a broad surface of contact with its seat, as in the case of a slide valve in the steam chest of an engine where the flanges have a broad lap.

Every designer of steam engines with slide valves finds the question asked of himself, "What force is necessary to slide the valve on its seat?" The first showing of an answer may be, "It depends on the pressure and the coefficient of friction." Probably but little is positively known about either the *effective* pressure, or the coefficient of friction in this case. The present object is to throw light upon the question of effective pressure.

To illustrate, suppose a common D slide valve has a surface contact with its seat of $12'' \times 12''$ outside, less a $5'' \times 10''$ D cavity inside as shown in Fig. 1, the cavity being supposed in communication with the exhaust. It seems evident that the effective pressure is not $p_1 \times 12 \times 12 = 144 p_1$ where p_1 is the pressure in pounds per square inch, because why may it not be merely the $p_1 \times 5 \times 10 = 50\ p_1$ as due to the cavity itself? The most thoughtful probably will assume some area between the inside and outside, in the neighborhood of that inclosed by the dotted line, by which to multiply p_1 for the effective pressure. This line I hereafter in this paper call the "*equilibrium line*," and the area inclosed within it the "*equilibrium area*," because the pressure p_1 multiplied by it, equals a force which, acting from below, will just lift the valve from its seat.

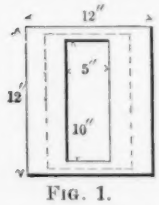


FIG. 1.

When the equilibrium area falls between that of the cavity and of the outside of the valve, it appears that the fluid pressing upon the top of the valve creeps under the edges to some extent, and that the film of fluid under the valve near the cavity relieves itself by escape into the cavity. It would seem from this reasoning—required for explaining the equilibrium line,—that for true surfaces a film of almost infinitesimal thinness is constantly creeping along between the "contact" surfaces, toward the cavity; and that on this route, the pressure of the creeping fluid is continually falling, starting with nearly that of the higher pressure side of the valve, and ending at the cavity with the pressure of the latter.

When the whole lifting pressure exerted by the creeping fluid between surfaces is known, the equilibrium line can be located. The theoretical determination of this lifting action is the same as that for finding the force tending to throw a packing ring from its seat. Formulas for the latter are given in the published transactions of this Society, Vol. II., pp. 27 and following, in my paper on *A Rational System of Piston Packing*. According to that paper it appears that for a rectangular valve like Fig. 1, and for an incompressible fluid, the pressure falls on a straight line declivity, from p to p_2; p being the pressure just at entry, and p_2 that within the cavity. The fall from p_1 to p is due to the acceleration for entry into the space. The latter, it is shown in the paper cited, will be a small fraction of the whole, and it will be neglected here.

In Fig. 2 let the shaded area stand for a section through a D slide valve like Fig. 1, the square outlines being best for the present purpose.

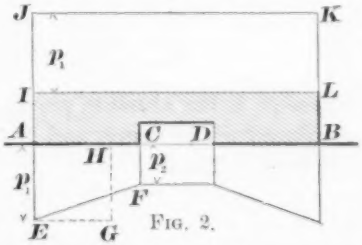


FIG. 2.

If p_1 be the absolute pressure on the top of the valve, and p_2 the absolute back pressure in the cavity; then according to what is said above, EF will represent the line of falling pressure from p_1 to p_2. Also it is evident that if the area $IJKL$ stands for the total absolute downward pressure upon the top of the valve, then the area $AEFC$ will represent the total absolute lifting pressure at one side of the valve, due to the creeping fluid along AC, and tending to raise the valve from its seat. Now draw EG parallel to AC, and make the area $AEGH = AEFC$, then the lifting pressure of the creeping fluid neutralizes so much of the top pressure $IJKL$ as lies directly over the length

AH. Hence H is the position of the equilibrium line. Likewise we may find the point on BD.

From the figure, it appears that AH will equal a half AC only when $p_2 = 0$.

As an example, suppose $p_1 = 60$, $p_2 = 15$. Then the mean pressure on AC is

$$P = \frac{p_1 + p_2}{2} = 37.5$$

and

$$P \times AC = p_1 \, AH,$$

or,

$$AH = AC \frac{P}{p_1} = AC \frac{37.5}{60} = AC \, .625.$$

Hence the equilibrium line is nearer C than A. More specifically, it appears that $62\frac{1}{2}$ per cent. of the pressure upon that part of the top of the valve which lies above AC and BD is counteracted by the lifting action of the creeping fluid.

This supposes the fluid incompressible like water (nearly so). Hence the above calculation is suited to the case of a valve working in water. For quite a range of pressure under this case, we may quote from the paper on piston packing referred to,

TABLE A.

$\frac{p_1}{p_2}$ =	$\frac{P}{p_2}$ =	$\frac{P}{p_1}$ =
2	1.5	.75
4	2.5	.625
6	3.5	.583
8	4.5	.562
10	5.5	.55

where p_1 is the absolute pressure upon the top of the valve, p_2 the absolute back pressure, and P the mean pressure due to the creeping fluid. Then

$$AH = AC \frac{P}{p_1}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

thus locating the equilibrium line.

If the fluid is elastic like air, and the flow in the space AC is adiabatic, we have from the same source,

TABLE B.

$\frac{p_1}{p_2}$ =	$\frac{P}{p_2}$ =	$\frac{P}{p_1}$ =
4	2.72	.68
6	3.94	.657
8	5.18	.647
10	6.42	.642

and for the isothermal flow of elastic fluids,

TABLE C.

$\frac{p_1}{p_2}$ =	$\frac{P}{p_2}$ =	$\frac{P}{p_1}$ =
4	2.80	.70
6	4.09	.682
8	5.41	.676
10	6.73	.673

These tables differ but little, and values may be selected to suit any case in hand, including even a condensable fluid like steam, because, whether steam, or water due to condensation, fills the space AC, the case will fall within the tables above. If any exception is to be made on the supposition that with steam the percentage of water will increase on the route from A to C, it will be to the effect that the lifting force is greater than the calculation would give, and hence on the safe side.

To illustrate further the use of the above tables and formula, suppose a D slide valve in a steam or air chest is 10 inches over all, and with a D cavity of 4 inches. Each flange will then be 3 inches if equal one to the other. Further, take

$$p_1 = 90\,;\ p_2 = 15.$$

Then

$$\frac{p_1}{p_2} = 6\,;\quad \begin{aligned} AH &= AC\ .682 \text{ or } AC\ .583 \\ &= 2.05 \text{ inches or } 1.75 \text{ inches,} \end{aligned}$$

if the last table be selected, or the first respectively.

Hence, doubling the values, we get for both flanges outside the equilibrium line

4.1 or 3.5 inches respectively,

or within the equilibrium line

5.9 or 6.5 inches respectively.

Hence the effective pressure of the valve upon its seat is as though the last named widths of equilibrium area only were subject to the pressure p_1.

The Equilibrium Line by Experiment.

In the spring of 1881, Student J. H. McEwen subjected this question of back pressure to experiment in my Mechanical Laboratory, as a practical problem in course. The appliance explained below was made by him for the purpose. In experimenting, the data were procured partly by Mr. McEwen and partly by Mr. C. F. Marvin. The results obtained from reducing the data to the valve, are given in plate I., p. 164.

The appliance employed is shown in section in Fig. 3, in which A represents the valve, B its seat, D the bed plate of the containing chest, C an inverted hollow piece, which, when bolted to D, together constituted the chest; G a nozzle for admitting the fluid pressure, H a cock for draining the chest, E a lever which, by means of a strut reaching up through the seat, will lift the valve A, and F, the scale pan for loading the lever.

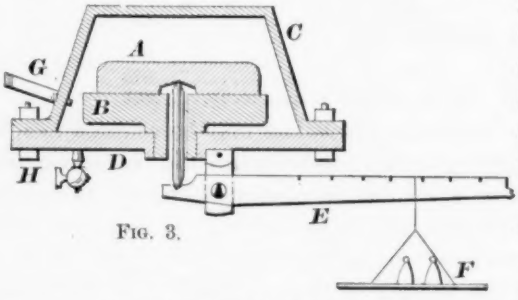


FIG. 3.

The valve and seat are circular in plan, and not rectangular. They were carefully fitted together by facing truly in a lathe, and then by grinding with emery. The grinding was done partly in the lathe and partly by hand with cross motion. It is perhaps to be regretted that this fitting was not done by scraping, but as they were, the surfaces possessed the properties of surface plates in high degree. Placing A upon B with clean joints, the former would float upon the latter for five or ten seconds, lubricated by air. When settled, A would lift B, and support it for a considerable time. The surfaces were mirror-like for smoothness throughout. Though the job was well done for grinding with emery flour, yet it is believed that a somewhat more satisfactory contact could have been obtained by the scraper. The outside diameter of the valve A is six inches, and its cavity two and a tenth inches. The seat B was about three-fourths of an inch larger than A outside, with a central aperture of about one inch. This excess of surface on B was intended for insuring contact on the entire lower surface of A, even should it get eccentric with B. The seat B was mostly free from the bed plate so as to relieve it from the strains and flexure of the latter. A neck projecting down from B was pressed into the bed, D, with a free space between B and D, thus supporting B on a short leg. The strut from the lever E nearly filled the central hole in D, and extended to the bottom of the cavity in A. This cavity in A was made conical at the center so that the strut would always carry A concentric and poised, as it was raised. The thickness of A and B was about two inches. The lever was borne on knife-edges.

Steam is the only fluid experimented with. It was admitted at the nozzle G. Condensed water was let out at H.

In the experiments, weights were put on till the valve was raised, or, as in some cases, the weights were shifted along the graduated lever. The pressure of steam in the chamber upon the top surface of the valve was varied from 10 to 84 pounds per square inch by gauge, or from 25 to 99 pounds per square inch absolute. The results reduced to the valve are given in the plate where the circle dots were obtained by one series of observations, and the cross points by another, the two series being several weeks apart in points of time. The vertical scale at the left is for the steam gauge pressures in the chamber. The horizontal scale gives the number of pounds pressure per square inch of the cavity area, which was necessary to lift the valve. The figures given in this scale were reduced to the valve from the experimental data read off from the weighted lever, the weight of the lever, scale-pan, strut and valve being taken into account; but not the atmospheric pressure to which the cavity under the valve was exposed. Hence the figures in both scales are apparent pressures per square inch, one for the entire area of the six-inch circle of the valve, and the other for the area of the circle of the cavity, two and one-tenth inches in diameter.

The curve running among the dots is supposed to be drawn where the sum of the squares of all the distances from the line to the dots is the least, that is to say, that line is the probability line for all the observations, according to the theory of "*least squares*." It is assumed, however, that the line should run through the origin. From this line the figures in the first two columns of the following table were read off.

TABLE D.—*For a circular valve* 6 *inches in outside diameter, with a circular cavity* 2.1″ *diameter exposed to the atmosphere.*

APPARENT PRESSURE, LBS. PER SQ. IN. ON VALVE 6″ DIAM. $p_1 - p_2$	APPARENT PRESSURE, LB. PER SQ. IN. ON CAVITY OF VALVE, 2.1″ DIAM. p^1	EQUILIB. AREA SUCH THAT $a'(p_1 - p_2)$ WILL JUST RAISE THE VALVE; SQ. INS. a'	DIAM. OF EQUILIBRIUM AREA; INS. $d.$
5	8.	5.6	2.6
10	17.	5.8	2.7
15	26.	6.0	2.8
20	36.	6.2	2.8
25	46.	6.4	2.9
30	57.	6.6	2.9
35	69.	6.8	2.9
40	81.	7.0	3.0
45	95.	7.3	3.0
50	112.	7.8	3.1
55	129.	8.2	3.2
60	150.	8.7	3.3
65	172.	9.2	3.4
70	198.	9.8	3.5
75	230.	10.5	3.7

A better notion of the quantities given in the table and plate perhaps can be obtained from Fig. 4, giving a section of the valve and its seat. Within the valve outline are drawn arching circles springing from the seat. These define the greatest and least equilibrium lines, which here are circles to the diameters 3.7″ and 2.6″ respectively, between which all the figures in the last column of the table fall.

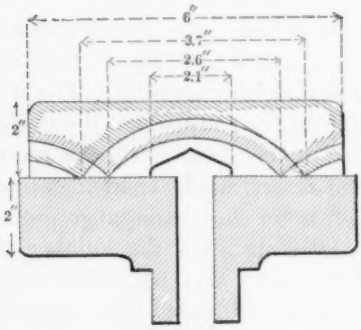


FIG. 4.

The interpretation of Fig. 4 is this:—For 75 pounds apparent pressure per square inch upon the top of the valve, the equilibrium circle is 3.7″ in diameter. That is, if the valve be taken from the chamber, and its seating face be turned off, or cut away with the exception of a sharp circular line to the diameter of 3.7″, so that when the valve is returned to its seat this circle is the only bearing of the valve upon its seat; then the same lifting force will be required to raise the valve from its seat as before, for this stated pressure of 75 pounds. Again when the stated apparent pressure is 5 pounds per square inch upon the top of the valve, then the same lifting force will raise it as when its face is cut away to a ring bearing of 2.6″ in diameter. In each case the atmospheric pressure is in full upon the cavity.

The relation between the pressures and areas may be expressed thus:

Let

p_1 = the absolute pressure per square inch within chamber;
p_2 = ordinary back pressure upon the cavity;
p^1 = lifting force per square inch of cavity, approximate;
P = mean absolute lifting pressure per square inch exerted by the creeping fluid between A and B, Fig. 3;
A = area of valve, here 6″ diameter;
a = area of valve cavity, here 2.1 diameter;
a^1 = equilibrium area.

Then,

$$p_1 A = p_1 (A - a^1) + p^1 a + p_2 a^1,$$

or,

$$a^1 (p_1 - p_2) = p^1 a$$

$$a^1 = a \frac{p^1}{p_1 - p_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

As an example, take the pressure $p_1 - p_2 = 50$ lbs. for the 1st column of table. Opposite this, in the 2d column, we find $p^1 = 112$ lbs. These in the above formula, observing that $a = 3.46$ square inches, give $a^1 = 7.8$ square inches, as found in the 3d column, for the equilibrium area. But this formula is only applicable to this particular valve.

It seems desirable that the theoretical formulas given above for rectangular valves be brought to the test of verification or disproof, by this series of experiments. To do so, it will be necessary to deduce a general formula for circular valves in the same way as was that for rectangular valves, and then compare that theoretical formula for circular valves with the experimental values of the table.

If the theoretical results agree with the experimental ones, then not only is the theoretical formula for circular valves verified, but that for rectangular valves also.

From my paper on *A Rational System of Piston Packing*, above referred to, page 27, we may quote

$$p - p_2 = \frac{\delta f s l}{a} \frac{v^2}{2g} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

as expressing the fall of pressure p to p_2 in a space conducting a fluid of invariable density δ, with the velocity v, where l is the length of the space, a its section, s the perimeter of its cross section, and f the coefficient of friction of the fluid upon the surfaces.

If the space be very thin with a thickness t, then for a unit's width we have $s = 2$ and $a = t$, so that

$$\frac{s}{a} = \frac{2}{t} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Then for a very short length we may put dx for l, and dp for $p - p_2$, giving

$$dp = \frac{2\,\delta}{t} f \frac{v^2}{2g} dx. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

applying this to the part *abcd* of the space *ABCD*, where the thickness is constant, the velocity of the incompressible fluid will vary as it moves from *AC* to *BD*. This velocity will, in fact, be inversely proportional to the distance from *O*, so that if v_2 = the velocity at *BD*, we have, if $r = BO$, $AB = b$, $AO = R$, and $aO = x$,

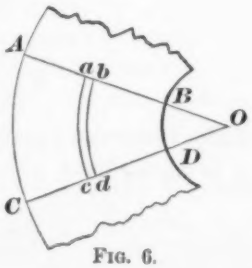


FIG. 6.

$$\frac{v}{v_2} = \frac{r}{x}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Then, replacing v by its value,

$$dp = \frac{2\,\delta f}{t}\ \frac{v_2^2}{2g}\ \frac{r^2}{x^2} dx. \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Integrating this between the limits aO and BO; or x and r, and p and p_2, we have

$$p - p_2 = \frac{2\,\delta f}{t}\ \frac{v_2^2}{2g} r^2 \left(\frac{1}{r} - \frac{1}{x}\right). \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Here p is the pressure in the space $ABCD$, at the line ad, situated at the distance x from O. This line is circular, and may be considered as extending to the entire circle about O. Then the absolute lifting pressure upon a circular strip of width, dx, and radius x is

$$p\ 2\ \pi\ x\ dx,$$

and for the entire under surface of the valve A, the total absolute lifting pressure is

$$P\ \pi\ (R^2 - r^2),$$

a quantity which is equal to the integral of the last expression above. Writing this equation, and at the same time introducing p from equation (8) above, we obtain

$$P\ \pi\ (R^2 - r^2) = \int_r^R \frac{2\,\delta f}{t}\ \frac{v_2^2}{2g} r^2 \left(\frac{1}{r} - \frac{1}{x}\right) 2\ \pi\ x\ dx$$

$$+ \int_r^R p_2\ 2\pi\ x\ dx,$$

$$= \frac{2\,\delta f}{t}\ \frac{v_2^2}{2g}\ \pi\ r^2 \left\{\frac{R^2 - r^2}{r} - 2\,(R - r)\right\} + p_2\,\pi\,(R^2 - r^2);$$

whence

$$P = \frac{2\,\delta f}{t}\ \frac{v_2^2}{2g} r^2 \left\{\frac{1}{r} - \frac{2}{R + r}\right\} + p_2$$

$$= (p_1 - p_2)\frac{R}{R + r} + p_2. \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

since, from the equation (8) for pressure, x being made $= R$, and $p = p_1$, we have

$$(p_1 - p_2)\frac{Rr}{R - r} = \frac{2\,\delta f}{t}\ \frac{v_2^2}{2g} r^2.$$

Dividing by p_2, we obtain

$$\frac{P}{p_2} = \left(\frac{p_1}{p_2} - 1\right) \frac{R}{R + r} + 1, \quad . \quad . \quad . \quad . \quad (10)$$

in which $R = b + r$ (see Fig. 5). Or if the relation of the mean absolute lifting pressure P, due to the creeping fluid, is desired in its relation to p_1, the last equation is readily modified to that end, viz.:

$$\frac{P}{p_1} = \left(1 - \frac{p_2}{p_1}\right) \frac{R}{R + r} + \frac{p_2}{p_1}. \quad . \quad . \quad . \quad . \quad (11)$$

These equations are for an inelastic fluid like water. For elastic fluids, even for the isothermal condition, the analysis is too complex to be introduced here for the circular valve. But for rectangular valves of the form of the ordinary slide valve, the solution is already given above in connection with Figs. 1 and 2. See Tables B and C, and equation (1).

But in comparing tables A, B and C, we observe that the mean lifting absolute pressure P, divided by the absolute pressure p_1 upon the top of the valve, gives a ratio which is nearly the same in the three tables, for any one pressure, p_1. Or, more briefly, it seems to make but little difference whether the fluid pressing upon the valve, and creeping along under it, is compressible like air and steam, or whether it is more nearly incompressible, like water. Hence, according to equation (1), it appears that the equilibrium line is nearly at the same position whatever the fluid, though for high pressures the differences in position are greatest. This fact enables us to make use of equation (11), and the theoretical position of the equilibrium line determined thereby for incompressible fluids, in comparing our theoretical results with the results of experiment in Table D.

The comparison thus made will enable us to judge of the value of Tables A, B and C, for use in calculating the position of the equilibrium line in ordinary cases of the slide valve.

For our circular valve it is plain that equation (1) will not answer. But regarding Fig. 2 as a section of a circular valve such as shown in Fig. 3, then to find what part of the top surface of valve under the pressure p_1 will be balanced by the P upon the under surface AC, we have

$$P\ (\pi\ R^2 - \pi\ r^2) = p^1\ (\pi\ R^2 - \pi\ x^2),$$

the first member being the total lifting pressure due to the creep-

ing fluid between the valve and seat, and the second member being the top pressure p_1 multiplied by such a part of the top surface taken uniformly around the outer edge of valve, as shall just counteract that lifting pressure.

In the last equation, x is the radius of the circle of the equilibrium line. Hence the diameter of that circle is twice the value of x from that equation, or

$$d = 2\,x = 2\,R\sqrt{1 - \frac{P}{p_1}\left(1 - \frac{r^2}{R^2}\right)}. \quad . \quad . \quad . \quad (12)$$

Here d stands for the same as given in the last column of Table D. Combining (12) and (11), we obtain

$$d = 2\,r\sqrt{\frac{R}{r} - \frac{p_2}{p_1}\left(\frac{R}{r} - 1\right)}. \quad . \quad . \quad . \quad . \quad (13)$$

for the diameter of the equilibrium circle for circular valves as found by theory for inelastic fluids.

Now values of d calculated by (13) should agree with the experimental values of the last column of Table D, except for the differences due to the fact that the theoretical values are for inelastic fluids, while the experimental values were obtained by experiments with steam, differences which have already been shown to be small.

A comparison of the theoretical values from (13), with the experimental values of the last column of Table D will, therefore, be of interest. This comparison is given in

TABLE E.—*Comparing Theoretical and Experimental Diameters of the Equilibrium Line for* $R = 3''$ *and* $r = 1.05''$.

APPAR. PRESS. PER SQ. INCH ON VALVE. $p^1 - p_2$	RATIO OF PRESSURES. $\frac{p^1}{p_2}$	LIFTING & SEATING PRESSURES. $\frac{P}{p_2}$	DIAMETER OF EQUILIBRIUM AREA. EXPERIMENTAL. d	CALCULATED. d	
5	1.33	.936	2.6	2.53	Probably 10 to 15 per cent. lower for elastic fluids.
10	1.67	.897	2.7	2.85	
15	2.	.871	2.8	2.92	
20	2.33	.852	2.8	3.02	
25	2.67	.838	2.9	3.09	
30	3.	.827	2.9	3.14	
35	3.33	.819	2.9	3.19	
40	3.67	.812	3.0	3.22	
45	4.	.806	3.0	3.25	
50	4.33	.801	3.1	3.27	
55	4.67	.797	3.2	3.29	
60	5.	.793	3.3	3.31	
65	5.33	.790	3.4	3.33	
70	5.67	.787	3.5	3.34	
75	6.	.785	3.7	3.35	
∞	∞	.741		3.56	

Though the last two columns are, for practical purposes, identical, yet it is to be remembered that perhaps a considerable difference is due to the fact of elastic and inelastic fluids as above mentioned.

To obtain some insight to the differences of calculated values for elastic and inelastic fluids, compare Table A for inelastic fluids with Table C for elastic fluids flowing isothermally; C being chosen in preference to B, because the differences are greater, but ranging here, however, mostly within 15 per cent. for values of $P \div p_1$. Though the law of velocity of the creeping fluid in circular valves differs from that in rectangular ones, giving cause for a difference in $P \div p_1$, for elastic and inelastic fluids which will not be exactly the same for rectangular as for circular valves, yet it is probable that these ratios of pressure will not be very far removed from each other. Assuming these differences identical for all forms of valve, and allowing the 15 per cent. range above mentioned, then putting in Eq. 12 values for $P \div p_1$, differing by 15 per cent. from those in Table E, we find that the corresponding calculated diameters of equilibrium areas are less by about 20 per cent. than those given in the last column of Table E. This throws the calculated values all to the other side of, or makes them smaller than, the experimental diameters of the equilibrium areas of the table, showing that for an elastic fluid these experimental diameters are high by about 10 per cent. This may perhaps be accounted for by the fact that during the experiments, when the chest was frequently opened to examine the valve, the seating surfaces were found to have upon them slight traces of a fine gray deposit, and this appeared to be most dense at and near the outer edge of the seating surfaces. The tendency of this would evidently be to keep the valve slightly elevated and to hinder the free entrance of the creeping fluid into the space under the valve and to favor its passage and escape after entrance, thus causing a greater effective pressure of valve upon seat and enlarging the experimental equilibrium areas to the figures observed, and to values higher than those calculated on the supposition of a purely elastic fluid flowing isothermally in a space of uniform thickness.

From these considerations it appears that the theoretical deductions are to be relied upon, and that the formulas resulting may be adopted in practice without hesitation. Formulas for elastic fluids and circular valves have not been worked out, but sufficient effort for them has been made to ascertain that such formulas would be

neither elegant nor convenient for use. But, fortunately, such formulas are mostly needed for rectangular valves with wide flanges on only two sides, as in slide valves for steam engines, for which case Tables A, B, and C will serve for all fluids and all requirements.

Practical formulas for calculating the equilibrium areas of ordinary rectangular slide valves of steam engines.

Let Fig. 6 represent a longitudinal section through one end of a double slide valve, with L the entire length over flanges, l the width of cavity, and q the width of the equilibrium area. It is evident that l must include cavities in the seat as well as in the valve, and perhaps bridges between. The side bearings of the valve, at the top and bottom of the cavity, are regarded as so narrow that they may be neglected.

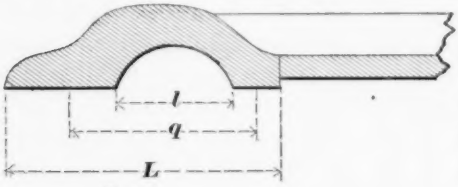


FIG. 6.

Then the upward pressure due to P against the entire under surface of the valve is

$$P\,(L - l),$$

and the part of the pressure upon the top of the valve which this equilibrates is

$$p_1\,(L - q),$$

which quantities are equal to each other. Equating and solving for q, we obtain

$$q = L\left\{1 - \frac{P}{p_1}\left(1 - \frac{l}{L}\right)\right\} \quad . \quad . \quad . \quad . \quad (14)$$

as the breadth outside of which the pressure p_1 is neutralized, and by which we are to multiply p_1 to obtain the effective pressure (absolute) upon the valve.

The total *effective* pressure of the entire half valve of Fig. 6 against its seat is, therefore,

$$Bq\,(p_1 - p_2) = B\,(p_1 - p_2)\,L\left\{1 - \frac{P}{p_1}\left(1 - \frac{l}{L}\right)\right\} \quad . \quad (15)$$

where B is the entire breadth of the valve.

As an example in application of (15), suppose a half valve be $L = 10''$, $B = 12''$, $l = 4''$, $p_1 = 90$ lbs. per sq. in., absolute, and $p_2 = 15$ lbs. per sq. in., or one atmosphere. Then Table A, for rect-

angular valves, gives $P \div p_1 = .583$, and the total effective pressure is, by (15),

$$12 \times 75 \times 10 \times \left\{ 1 - .583\ (1 - .4) \right\} = 5850 \text{ lbs} \quad . \quad (16)$$

where the total pressure upon the entire half valve is

$$12 \times 75 \times 10 = 9000 \text{ lbs.}$$

which latter, it appears, will never be exerted for pressing the seating surfaces together.

The resistance to sliding for the half valve will be

$$5850\, f,$$

where f is the coefficient of friction, the value of which no attempt is made to elucidate in this paper.

The result (16) would evidently have been the same had the cavity been placed at the middle in Fig. 6, as in ordinary slide valves.

For circular valves find d from equation (13), and Table E. Then the total effective pressure of valve against its seating surfaces, is

$$\tfrac{1}{4}\, \pi\, d^2\, (p_1 - p_2) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

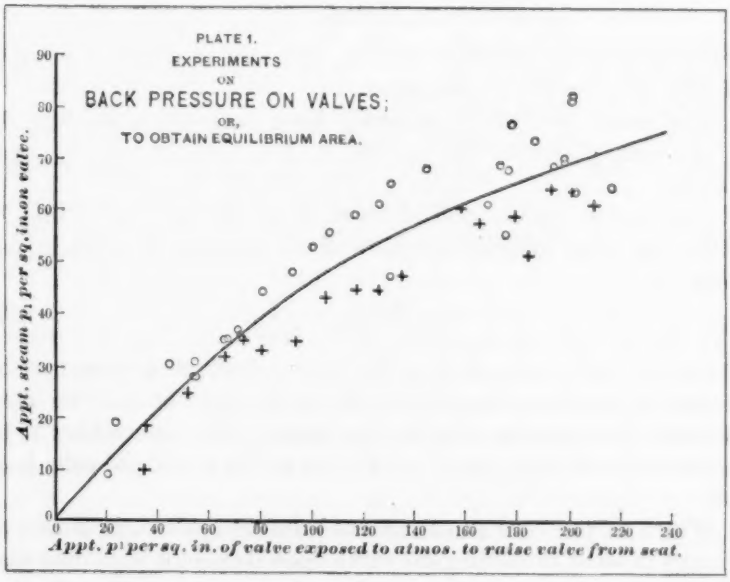
Conical valve seats, such as for wing valves of pumps, may be treated as circular surfaces where the slant height of the cone is R, etc., and d in equation (13) may be found. The cone is then to be developed, and such part of $\frac{1}{4}\, \pi d^2$ used as the developed cone is of 360°.

Where valves have an extraneous pressure applied, as in case of springs to assist in holding the valve upon its seat, it is evident that this pressure is to be added to that above obtained for effective pressure. Such spring pressure will in effect figure the same as the pressure on top of the valve over the cavity.

It may be remarked that the ratio of pressure $P \div p_1$ is for small lifts of valve independent of the thickness of the space between valve and seat. From this fact we are to conclude that the same force which starts the valve upward from its seat in lifting it, is to be continued until the space becomes so thick that the accelerative force required to give the escaping fluid its motion, becomes so great as to absorb an appreciable portion of the total head causing flow. The acceleration to be accounted for in this problem is that at entry to the space, and also along the space to the exit, the

accelerative force along the space between valve and seat would be nil for rectangular valves and inelastic fluids, but not for others. These points are important to a rational theory of perfect "pop" safety valves.

It is advisable to observe here that the experimental results given in this paper serve not only to confirm the theory of the equilibrium line, etc., for valves, but that the theory of packing rings as given in the paper on *A Rational System of Piston Packing*, above cited, based upon the same principles, also receives confirmation in the same degree.



BELTING TO CONNECT SHAFTS WHICH ARE NOT PARALLEL AND DO NOT INTERSECT.

BY

J. BURKITT WEBB, CORNELL UNIVERSITY, ITHACA, N. Y.

(Read at the first regular meeting of 1882.)

HAVING found incomplete and inaccurate statements with regard to the setting of pulleys for twist-belts in some of our standard works on mechanism,* I have endeavored to investigate the subject more exactly.

The general law governing all cases of flat belting is, that the "point of departure" of the belt from one pulley must lie in the "belt-plane" of the other.

The following terms have been adopted for convenience:

Point of Departure.—The point Z (or Z'), Fig. 1, at which the belt leaves the pulley and enters upon the *Belt-tangent*, ZX' (or $Z'X$), which is the straight portion of the belt, tangent to both pulleys and reaching from Z (or Z') to the *Point of Arrival*, X' (or X). From this point the belt follows the *Circular Belt-arc* $X'Y'$ (or XY) in contact with the pulley. The plane of this arc is perpendicular to the pulley-axis, and will be called the *Belt-plane*. This, as will be seen, is parallel to, but not necessarily the same as, the central plane of the pulley. At the *Slipping point*, Y' (or Y) the belt begins to slip sidewise, running in a curve of double curvature, which we shall call the *Cylindrical Catenary*, from Y' (or Y) to Z' (or Z). This curve is cylindrical inasmuch as it lies on the surface of the pulley, while upon the development of that surface it is a common catenary with vertex at Y' (or Y).

* Among others we have this from Weisbach: "Zu diesem Zwecke hat man die beiden Räder, Fig. 190, so gegen einander zu stellen, und den Treibriemen so aufzulegen, dass *die gerade Verbindungslinie, AC, der beiden Ablaufspunkte in den Durchschnitt der beiden Radebenen hineinfällt*, indem alsdann offenbar der Ablaufspunkt eines jeden Rades in der Ebene des anderen Rades liegt. Diese Linie, *AC*, ist übrigens, wie leicht zu erkennen, dem kürzesten Abstande, *MN*, beider Axen gleich und parallel." [Die Mechanik der Zwischen und Arbeitsmaschinen, von Dr. Julius Weisbach. Dritter Theil, erste Abtheilung, 8, 284. Zweite Auflage, Vieweg und Sohn, Braunschweig.] It is true that Fig. 190 represents apparently two shafts at right angles, but the statement is not confined to this shaft-angle.

An element of the cylindrical surface of the pulley drawn through Y' (or Y), is the axis of the catenary, and the parameter is the radius of the pulley divided by the co-efficient of friction between it and the belt. The circular belt-arc is tangent to it at Y' (or Y), and the belt-tangent at Z' (or Z). The *Perpendicular-tangent*, AA', is a limited line perpendicular to both the shafts, and at distances therefrom respectively equal to the radii of the pulleys. If the shafts be horizontal, and the pulleys be so set as to be tangent to a plumb-line, the perpendicular-tangent coincides with this line, and connects the point of tangency. This is indicated by the dotted position of the pulleys in Fig. 1. By means of a "shipper" on one of the belt-tangents we may force the belt to run in any desired position, having (for the other belt-tangent) its own point of departure and point of arrival, for which we will employ z and x, using the capital letters, Z and X, for the natural position only of the belt. By connecting all the points of arrival and of departure, we obtain curves of arrival and of departure. The *Curve of Arrival* is a curve of double curvature upon the cylindrical surface of the pulley, as is also the *Curve of Departure*. These curves may be defined geometrically as the loci of the points of tangency of the common tangent to two cylinders, the tangent to be drawn perpendicular to the axis of that cylinder on which the curve of arrival is to be generated. The upper and lower elements of each cylinder are asymptotes to the curves upon it. The horizontal projection of the intersection of the belt-planes will be denoted by s, and the locus of this point will be called the *Curve of Intersection*. With the "shipper" upon one belt-tangent we may generate the locus of s, and by shipping the other belt-tangent we may generate the locus of s'. In the natural position of the belt, s and s' will be the same, the curves intersecting in this point, which we will call S. The natural position, or position of equilibrium of the belt is that position in which it will run with no shipper upon either belt-tangent. The *Shaft-angle* is the angle θ, between the shafts, and the *Belt-angle* is the angle γ (or γ') which the belt-tangent makes with that shaft with which it is not at right angles.

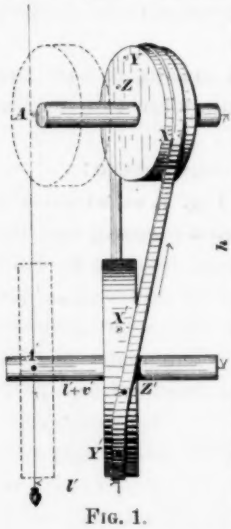


FIG. 1.

It has been sometimes assumed that the dotted position in Fig. 1 is correct for any shaft-angle; but it can be shown that it is not, either by examining the circumstances that determine the position of the belt or by constructing the simplest model. It has been stated inaccurately that a line, ZZ', which may be called the "*departure connective*," coincides with the intersection of the belt-planes, and still further that it is identical with the *perpendicular-tangent*. Neither statement is correct, though for shafts at right angles, the perpendicular tangent falls in the intersection of the belt-planes.*

The proper position of the pulleys may be found as follows:

Let, P and P', Fig. 2, be the upper and lower pulleys in horizontal projection; there will be four positions as shown. If the pulleys run as indicated by the arrow to the left, both points of departure will be projected near a; this is also the position of the pulleys in Fig. 3, where the course of the belt is also shown. By reversing both shafts, we obtain the position d, whereas if the lower (or upper) shaft alone be run backward, we have b (or c). These positions, however, correspond to the dotted positions in Fig. 1, and are therefore only approximate.

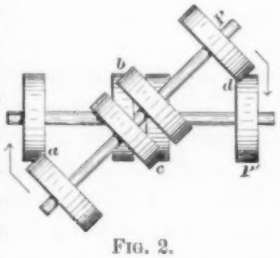
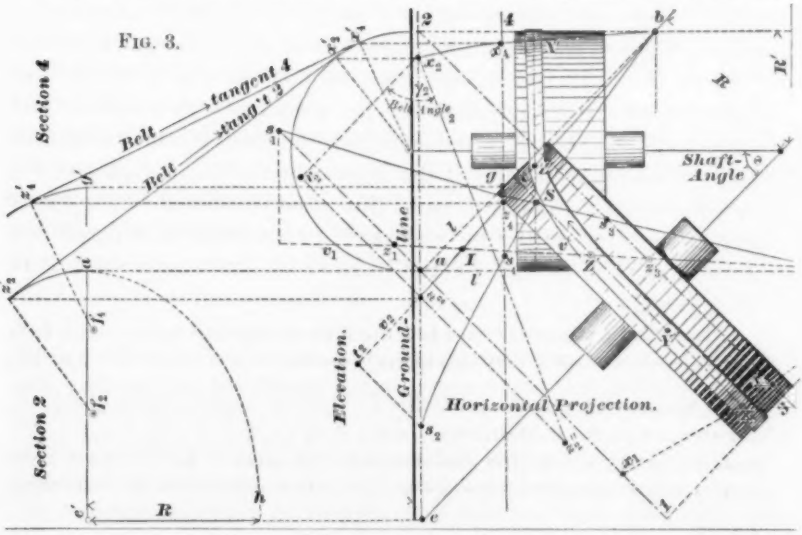


Fig. 2.

Fig. 3 shows the method of finding the exact positions on the as-

Fig. 3.



* See previous note.

sumption that we may neglect the stiffness edgewise of the belt, and also that the unequal tension on the edges of the belt does not curve its straight portions.*

Having given the sizes of the pulleys and the directions of their motion, also the angle and distance between the shafts, we suppose the pulleys to be extended into drums or cylinders, of which we draw the horizontal projections. These will consist of projections of the exterior elements, which will intersect each other in four points, a, b, c, and d, Fig. 2—a and b only appearing in Fig. 3. Pass now a series of planes 2, 4,—b, perpendicular to the lower shaft; these will cut circular sections of radius, R', from the lower cylinder, and from the upper, ellipses having R for a minor axis, and a major axis equal to $\frac{R}{\cos \theta}$. To the left of the (heavy) ground-line are shown the sections cut out by the planes 2 and 4. Plane 2 cuts the first element of P at a, and the center of its shaft at e; by projecting these two points to a height h above the ground line, we obtain the center, e', and vertex, a', of the ellipse. As a small part only of this curve is needed, we can approximate to this by a circular arc with its center at f_2. The ground line is here chosen at the height of the lower shaft, so that the section cut from P^1 appears as a semicircle. For plane 4 this semicircle is still the lower section, but the upper is found by projecting the point g (instead of a) to g', for the vertex of the ellipse. Having made these sections, we draw the belt-tangents, $z_2'x^{2'}$ and $z_4'x_4'$, which appear here in their true lengths, and obtain the points of departure, z_2', z_4', and of arrival, x_2', x_4'. Projecting these back, we get their horizontal projections, z_2, z_4, x_2, x_4, and, as it is clear also that b is both a point of departure and of arrival in horizontal projection, we may draw the horizontal projections of the "curve of departure," z_2z_4b, and of the "curve of arrival," x_2x_4b. The former curve belongs to the upper cylinder, and its projection is tangent to the horizontal projection of its outside element at b; the latter to the lower and tangent in the same way at b.

* The stiffness edgewise of the belt will tend to make the curve longer from Z to Y, but at the same time the unequal tension on the edges after the belt leaves the pulley at Z tends to curve the belt-tangent, and may thus more than counterbalance the former effect; in fact, with two pulleys, 12 in. and 16 in diameter, on shafts at right-angles and 7 feet apart, the tension was so unequal on the edges of a three-inch belt that the point of departure was more than an inch away from the belt-plane of the other pulley, and the belt bulged up in a wrinkle toward one edge before reaching the point of departure.

In precisely the same manner, by means of the planes, 1, 3, etc., perpendicular to the axis of the upper cylinder, we obtain a curve of arrival, x_1x_3c, (on the under side of the upper cylinder), and a curve of departure, z_1z_3c (beneath the lower cylinder). The intersection I, of the projections of the two curves of departure, would be the projection of the intersection of the belt-planes, if the belt did not slip sidewise before reaching the curves of departure.

To allow for this slipping we must find the belt-angle, γ, which the belt tangent forms with the element of the cylinder passing through the point of departure.

For the point of departure b, $\gamma = 90°$, and it decreases gradually as the point of departure moves away from b, along the curve of departure. To find γ_2 for the point z_2, we notice that z_2x_2 is the horizontal projection of the belt-tangent, and that a line through x_2, parallel to the elements of the upper cylinder, will have x_2r_2 as its horizontal projection, and will make with the belt-tangent the angle γ_2, whose projection is the angle $r_2x_2z_2$. To find the true value of γ_2 we drop from z_2 the perpendicular z_2r_2 upon r_2x_2; this will be the horizontal projection of the perpendicular of the right-angled triangle, $z_2r_2x_2$, in space, of which the belt-tangent is the hypothenuse; if now we revolve this triangle about r_2x_2 until it becomes horizontal, z_2, will fall at z_2'', this point being found by producing r_2z_2 and cutting it with x_2z_2'', made equal to the true belt-tangent length, $x_2'z'$, obtained from the section. We then find, $\gamma_2 = r_2x_2z_2''$.

It will be seen in Fig. 1 that l' is the distance from the plumb-line or perpendicular-tangent (marked a in Fig. 3) to the belt-plane, while $l' + v'$ is the distance to the point of departure, so that v' is the distance of this point beyond this plane: in other words, v' is the ordinate of the point of departure and of the catenary arc. According, then, to the laws of this curve, v is dependent upon γ in a very simple manner; in fact, if we put α = coefficient of friction, we shall have

$$v = \frac{R}{\alpha} \cdot \frac{1 - \sin \gamma}{\sin \gamma};$$

that is to say, if we construct a triangle similar to $x_2r_2z_2''$ with its perpendicular (side opposite γ) equal to $\frac{R}{\alpha}$ the parameter of the upper catenary, then v will be the difference between its perpendicular and hypothenuse. Having found v_2, (corresponding to plane 2, Fig. 3), we lay it off from z_2 to t_2, parallel to the upper axis, and

complete the right-angled triangle $z_2 t_2 s_2$, or we may simply lay off $z_2 s_2 = \frac{v_2}{\sin \theta'}$. In the same way we obtain v_4 and find the point s_4, and complete this part of the work by drawing the curve of intersection through $s_2 s_4$ and b.

We proceed now in the same way for the lower pulley, remembering that $\frac{R'}{\alpha}$ is the parameter of its catenary, and obtaining the curve $s_1 s_3 c$. The intersection S of these two curves is the horizontal projection of the intersection sought of the belt planes, whose projections we can at once draw. Where these planes intersect, the curves of arrival and departure are the true points of arrival and departure, X, X', Z, and Z'. The slipping points, Y, Y', are not needed, but may be found from the fact that the length of the upper catenary arc is $\frac{R}{\alpha \tan \gamma}$, and of the lower $\frac{R'}{\alpha \tan \gamma'}$, γ and γ' being the angles corresponding to Z and Z'.

The manner in which the belt runs can now be understood: Arriving at X it follows the belt-arc to Y, where it begins to slip out of the belt-plane, so that by the time it arrives at Z it is a distance v from the plane. It now finds itself in the other belt-plane, and follows the belt-tangent to X', where it enters on the lower belt-arc, which it follows to Y' (not shown), and then commences slipping, so that when it reaches Z' it is v' away from the lower belt-plane and back again in the upper. $Z'X$ then completes the circuit to X.

It will be seen that the belt-planes do not lie in the centers of the pulleys, which, if "coned," should have their largest diameters in the belt-planes. The faces should also be wide enough to include the points of departure with a proper margin.

We will now deduce the equation of the catenary on the supposition that the belt slips enough on the pulley to prevent any standing friction.

In Fig. 4 we have the development (not drawn to scale) of that part of the upper pulley on which the belt runs; the curve of departure is at the top and the curve of arrival at the bottom. The curve sought is evidently tangent at the origin Y, to the axis of the abscissas YU, and at Z to the belt tangent, which makes an angle γ with YV. This axis is also seen to be the production of XY, the development of the circular belt-arc; YV, perpendicular thereto, is the axis of ordinates. The lower horizontal line

represents the outside element of the pulley, near the point of arrival X.

To investigate the nature of the curve YZ we will examine two consecutive elements of the cylindrical surface; these will be represented in Fig. 4 by the horizontal line passing through W. We will suppose these elements to be of the same width $= du$, and, in order to examine them closely, we will suppose the intersection at W to be magnified 8 times, which will give us Fig. 5.

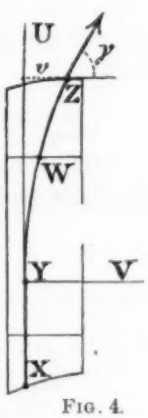


Fig. 4.

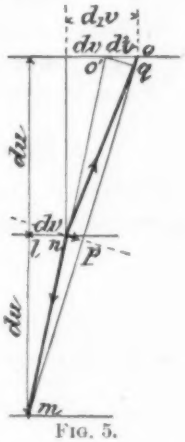


Fig. 5.

In this figure linear first differentials appear as finite quantities; mn and no are the two consecutive elements of the curve; these are supposed to be upon the undeveloped surface of the cylinder, and we shall therefore have m and o and the edges of the elements of the cylinder lying in the plane of the paper, while n and the junction of these elements will lie at a distance above the paper $= \frac{du^2}{2R}$. Inasmuch as the second element of the curve makes but a differential angle with the first, it should appear to fall upon no', which is the prolongation of mn; but in order to separate the lines to the eye it is drawn at no; this also makes $oo' = d^2v$ appear of a finite size, whereas it should not show upon this figure if drawn correctly. mn and no form two sides of a triangle, of which mo (in the plane of the paper) is the base, and np the altitude; the plane of this triangle is inclined to the plane of the paper, which latter is perpendicular to the radius of the cylinder.

To apply now the principles of mechanics to the problem:—At n we have two equal and opposite belt-tensions, represented by the arrows in the directions nm and no; as, however, no makes with mn a differential angle, these tensions will have a differential resultant in the direction np, Fig. 6 (np, Fig. 5, being its projection), as indicated by the arrow. If now we pass a plane through np and perpendicular to the paper, it will contain not only this resultant, but also the radius of the cylinder through n, as well as the intersections of the plane with the paper and with the surface of the cylinder. This section (indicated by the dotted line through np) is shown in-

finitely magnified in Fig. 6, where nn_1 is a portion of the cylinder radius through n, and the horizontal lines are the two intersections. In Fig. 6 second differentials appear as finite quantities.

FIG. 6.

The belt at n, Fig. 6, being urged by a force in the direction np will slip along on the surface of the cylinder until the

$$\tan pnn_1 = \frac{pn_1}{nn_1} = \alpha = \text{coefficient of friction};$$

this gives us at once the value of the projection of pn on the plane of the paper (n_1p in Fig. 6 and np in Fig. 5),

$$pn_1 = \alpha \times nn_1 = \alpha \frac{du^2}{2R}.$$

Dropping now the perpendicular $o'q$ upon mo, we have its value twice that of $np = pn_1$,

$$o'q = \alpha \frac{du^2}{R},$$

but as $\frac{R}{\alpha}$ will be found to be the parameter of the catenary, we may at once write $o'q = \frac{du^2}{p}$.

We have now the triangle, $o'qo$, right-angled at q, and similar to mln, and therefore we may write the value of $d^2v = o'o$.

$$d^2v = \frac{du^2}{p} \cdot \frac{\sqrt{du^2 + dv^2}}{du} = \frac{du}{p} \cdot \sqrt{du^2 + dv^2}.$$

(The dv at o is of course greater than dv at n; to indicate this we have put at o, $d_1v = dv + d^2v$.)

As du is constant, this may be put in the following form for integration:

$$\frac{dvd^2v}{\sqrt{du^2 + dv^2}} = \frac{dudv}{p},$$

which, integrated, becomes

$$\sqrt{du^2 + dv^2} = \frac{v + p}{p} du,$$

or,

$$dv = \frac{\sqrt{v^2 + 2vp}}{p} du.$$

To integrate again write this in the form,

$$\frac{dv}{\sqrt{v^2 + 2pv}} = \frac{du}{p},$$

and introduce a new variable by putting

$$\sqrt{v^2 + 2pv} = z + v,$$

which reduces the equation to

$$\frac{dz}{p - z} = \frac{du}{p}.$$

Integrating this and changing the result to the exponential form, we have

$$\frac{p - z}{p} = e^{-\frac{u}{p}},$$

in which the original variable, v, must be replaced; it will simplify the result, also, if we add to each member of the equation its own reciprocal. This gives, after reduction,

$$\frac{v + p}{p} = \frac{e^{\frac{u}{p}} + e^{-\frac{u}{p}}}{2},$$

as the equation sought of the curve. It is therefore the common catenary with a parameter $= p$.

Differentiating and remembering that

$$\sin \gamma = \frac{du}{\sqrt{du^2 + dv^2}}$$

we easily obtain the equation previously given.

$$v = p\frac{1 - \sin \gamma}{\sin \gamma}.$$

The length of the catenary arc is also easily found to be

$$s = p \text{ cotang. } \gamma.$$

We will now produce the equation of the curves of departure, and of the curves of intersection, which last also pass respectively through b and c.

In Fig. 7, which, like Fig. 5, is a horizontal projection, let the curves sought be referred to the oblique axes, aJ and aK, for the upper pulley (and aJ' and aK' for the lower). Let also k_1 be the ordinate of the curve of departure, and k_2 the additional distance to

the curve of intersection, so that $k_1 + k_2 = k$ is the ordinate to the curve, j being the common abscissa of both. aJ and aJ', are coincident with the outside elements of the upper and lower pulleys, while aK is perpendicular to the lower shaft, and aK' to the upper.

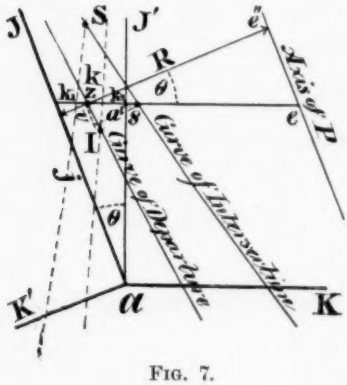


Fig. 7.

In Fig. 8 let $zg'ee'$ be a section through zse, Fig. 7, by a plane perpendicular to the lower axis, with a perspective of lines not in that section, drawn heavier when in front of the plane, and dotted when behind. R, in both 7 and 8, is the radius of the upper pulley to a point of departure z, and R makes with the horizontal plane through the axis the angle φ, as seen in Fig. 8: we will use φ as the independent variable, and express the js and ks in terms of it. In Fig. 8 the angles marked with an ⌞ are right-angles, the semicircle shows the section cut out of the lower pulley, and the two curves shown as cut out of the upper pulleys are, the one an arc of the ellipse cut out by the plane of the section, $zg'ee'$, and the other a circular arc cut out by the plane through z perpendicular to the upper shaft.

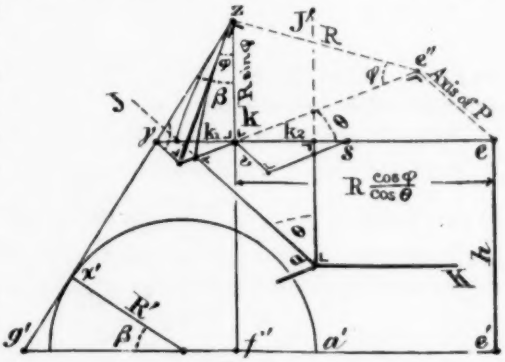


Fig. 8.

A comparison of the figures shows that in Fig. 7

$ze'' = R \cos$,

and therefore that

$$k_1 = \frac{R(1 - \cos\varphi)}{\cos\theta}, \quad \ldots\ldots\ldots \quad (I)$$

also, we see that

$$k_2 = \frac{v}{\sin\theta}.$$

Now the value of v depends upon γ, and γ depends upon φ; in fact, we found in the discussion of the catenary that

$$v = p\,\frac{1 - \sin\gamma}{\sin\gamma},$$

and in Fig. 8 we find

$$\operatorname{cotan}\gamma = \sin\varphi\,\tan\theta,$$

from which comes

$$\sin\gamma = \frac{1}{\sqrt{\sin^2\varphi\,\tan^2\theta + 1}},$$

so that by substitution we get

$$k = \frac{p}{\sin\theta}\left(\sqrt{\sin^2\varphi\,\tan^2\theta + 1} - 1\right).$$

Remembering also that

$$p = \frac{R}{\alpha},$$

we may write finally,

$$k = k_1 + k_2 = R\left[\frac{1 - \cos\varphi}{\cos\theta} + \frac{\sqrt{\sin^2\varphi\,\tan^2\theta + 1} - 1}{\alpha\,\sin\theta}\right]. \quad \text{(II)}$$

The value of j must also be expressed in terms of φ. We have, therefore, in Fig. 7,

$$ea' = \frac{R}{\cos\theta} - j\,\sin\theta.$$

But ea', Fig. 7, is the same as $e'a'$, Fig. 8, where it has the value

$$e'a' = e'f' + f'g' - g'a'.$$

These three distances are seen in Fig. 8 to be

$$e'f' = R\,\frac{\cos\varphi}{\cos\theta}$$

$$f'g' = zf'\,\tan\beta, \text{ but } zf' = h + R\,\sin\varphi,$$

so that

$$f'g' = (h + R\,\sin\varphi)\,\tan\beta.$$

$$g'a' = R'\,\frac{1 + \cos\beta}{\cos\beta}.$$

We find also in Fig. 8 that

$$\tan\beta = \frac{\tan\varphi}{\cos\theta},$$

and that therefore

$$\frac{1}{\cos\beta} = \frac{\sqrt{\tan^2\varphi + \cos^2\theta}}{\cos\theta};$$

substituting these values, and solving for j we obtain

$$j \sin\theta \cos\theta = R\,(\sqrt{\tan^2\varphi + \cos^2\theta} + \cos\theta) - R\,\frac{1-\cos\varphi}{\cos\varphi} - h\tan\varphi, \quad . \quad . \quad . \quad . \quad \text{(III)}$$

I, II and III are therefore the equations for the curves of departure and intersection for P. Similarly for P' we have

$$k' = R'\,\frac{1-\cos\varphi'}{\cos\theta}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(I')}$$

$$k' = R'\left[\frac{1-\cos\varphi'}{\cos\theta} + \frac{\sqrt{\sin^2\varphi'\tan^2\theta + 1} - 1}{\alpha\sin\theta}\right], \quad \text{(II')}$$

$$j' \sin\theta\cos\theta = R\,(\sqrt{\tan^2\varphi' + \cos^2\theta} + \cos\theta) - R'\,\frac{1-\cos\varphi'}{\cos\varphi'} - h\tan\varphi', \quad . \quad . \quad . \quad \text{(III')}$$

The intersection S must satisfy at once II, III, and II', III', which may be expressed analytically by writing

$$j\sin\theta = k + k'\cos\theta, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(IV)}$$

$$j'\sin\theta = k' + k\cos\theta, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(IV')}$$

By first using IV and IV', and then II and II' we may reduce III and III' to two equations between φ and φ'; it will be easier, however, to use II, III and II', III' to draw portions of the curves of intersection, and thus to find S graphically.

When tables have been calculated for a particular co-efficient of friction, and it is desired to obtain results for a different and preferably greater co-efficient, it can be done with sufficient accuracy by including in the tables columns giving that portion of $j\cos\theta$ (or $j'\cos\theta$), which is the projection on j' (or j) of SI, Fig. 3 or Fig. 7, it being only this portion which varies when α is changed.

Those who may be disposed to test the practical accuracy of the positions obtained as above will confer a favor by reporting the results to the author. To put the matter in a convenient shape for any such tests, as also for practical use, the following partial tables have been prepared, with no pretension, however, to great accuracy.

To test the tables, narrow belts should be used, as no lateral stiffness has been allowed for.*

TABLES

For finding the positions of pulleys on non-intersecting, non-parallel shafts. The results are not given farther than 60°. For $\theta = 90°$ and 270°, $l_0' = 0$. The following is the complete notation, part of which is in the figures.

D' = diameter of lower pulley $= 2\ R'$.

R and R' = radii of upper and lower pulleys.

h = height of upper shaft above the lower.

θ = angle between the shafts.

α = co-efficient of friction between belt and pulley.

$\alpha_0 = 0.2$ = the value of α employed in the tables.

l and $l' = j \cos \theta$ and $j' \cos \theta$ = distances of the upper and lower belt-planes from the perpendicular-tangent, *i. e.*, from the point a Fig. 3.

l_0 and l_0' = the values of l and l' for $\alpha = \alpha_0$ and $D' = 1$.

λ and λ' = the parts of l_0 and l'_0 dependent on the friction.

v, v', v_0 and v_0' = distances of Z and Z' from their belt-planes; the pulleys should therefore be made this much wider than is usual for parallel shafts.

For values of α and D' other than $\alpha = \alpha_0 = 0.2$, and $D' = 1$, we have, with sufficient accuracy,

$$l = \left(l_0 + \lambda \frac{\alpha_0 - \alpha}{\alpha_0} \right) D'$$

and

$$l' = \left(l'_0 + \lambda' \frac{\alpha_0 - \alpha}{\alpha_0} \right) D'.$$

Also

$$v = v_0 \frac{\alpha_0 - \alpha}{\alpha_0} D'$$

and

$$v' = v'_0 \frac{\alpha_0 - \alpha}{\alpha_0} D'.$$

If, then, all the linear quantities in the tables are supposed to be inches, they will correspond with a lower pulley of one inch diameter.

[*See previous note.]

$R = R'$

h	$\psi°$	l_0	λ	v_0	l'_0	λ'	v'_0
2	15	.65	.31	.01			
	30	.41	.26	.04			
	45	.21	.16	.07			
	60	.15	.12	.18			
3	15	.37	.20	.01			
	30	.23	.16	.02			
	45	.12	.09	.04			
	60	.09	.07	.09			
4	15	.22	.11	.00			
	30	.14	.10	.02	$l'_0 = l_0$	$\lambda' = \lambda$	$v'_0 = v_0$
	45	.08	.07	.03			
	60	.06	.05	.05			
6	15	.11	.06	.00			
	30	.07	.05	.01			
	45	.04	.03	.01			
	60	.03	.02	.03			
10	15	.06	.02	.00			
	30	.03	.02	.00			
	45	.02	.02	.00			
	60	.02	.02	.01			

$R = 2\,R$

h	$\varphi°$	l_0	λ	v_0	l'_0	λ'	v'_0
3	15	.88	.41	.01	.87	.41	.02
	30	.55	.34	.03	.52	.32	.08
	45	.35	.26	.07	.30	.22	.16
	60	.24	.20	.10	.18	.15	.26
5	15	.43	.22	.00	.42	.22	.01
	30	.27	.18	.02	.26	.17	.04
	45	.17	.14	.04	.15	.12	.07
	60	.11	.10	.05	.09	.08	.12
7	15	.23	.12	.00	.23	.12	.00
	30	.16	.10	.01	.15	.09	.02
	45	.10	.07	.02	.09	.07	.04
	60	.07	.06	.03	.05	.04	.07
11	15	.10	.05	.00	.09	.05	.00
	30	.07	.05	.00	.07	.05	.01
	45	.04	.03	.01	.04	.03	.02
	60	.03	.02	.02	.03	.02	.03

$R = 3\ R'$

h	$\theta°$	l_0	λ	v_0	l'_0	λ'	v'_0
4	15	1.04	.50	.01	1.02	.49	.05
	30	.65	.41	.02	.59	.37	.12
	45	.44	.33	.05	.36	.26	.22
	60	.23	.17	.09	.17	.11	.40
7	15	.43	.22	.00	.43	.22	.01
	30	.35	.24	.01	.32	.21	.06
	45	.19	.16	.03	.16	.13	.09
	60	.13	.10	.04	.09	.07	.15
10	15	.20	.10	.00	.20	.10	.01
	30	.15	.10	.01	.14	.09	.03
	45	.10	.08	.02	.09	.07	.05
	60	.07	.06	.02	.05	.04	.08
16	15	.08	.04	.00	.08	.04	.00
	30	.07	.05	.00	.07	.05	.01
	45	.05	.04	.01	.04	.03	.02
	60	.03	.02	.01	.02	.02	.03

$R = 4\,R'$

h	$\theta°$	l_0	λ	v_0	l'_0	λ'	v'_0
5	15	1.09	.52	.01	1.06	.50	.04
	30	.72	.47	.02	.65	.41	.13
	45	.50	.38	.04	.39	.29	.32
	60	.36	.30	.06	.21	.17	.46
8	15	.50	.25	.00	.49	.24	.02
	30	.36	.25	.01	.33	.23	.06
	45	.25	.20	.02	.20	.15	.13
	60	.16	.14	.04	.11	.09	.20
11	15	.29	.15	.00	.28	.15	.01
	30	.21	.14	.01	.19	.13	.04
	45	.14	11	.02	.12	.09	.07
	60	.10	.08	.03	.07	.06	.11
17	15	.13	.07	.00	.13	.07	.00
	30	.11	.08	.00	.10	.07	.02
	45	.07	.06	.01	.06	.05	.03
	60	.05	.04	.01	.04	.03	.05

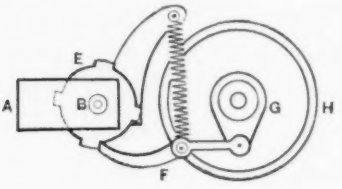
As the positions of λ' and λ'' are not needed in setting the pulleys, the lengths of the catenary arcs are not given in the tables. In some of the positions these arcs are of such extent as to render the positions impossible for low co-efficients of friction. Should the principle above developed be found to be in near accordance with experimental results, more complete tables may be calculated, which should include the lengths of the circular belt-arcs. This would furnish the data for an estimation of the varying amount of power which can be transmitted when the distance between the shafts is varied, this amount evidently depending to a large extent upon the lengths of the circular belt-arc; the limits of approximation of such shafting would thus become known.

A NEW FORM OF STEAM ENGINE INDICATOR.

BY

PROF. J. BURKITT WEBB, ITHACA, N. Y.

It has been my endeavor to devise a form of indicator which should work with high-speed engines, and I think I have hit upon a principle—a new principle, perhaps—which accomplishes the object. If, after having explained it, some should say that it is not new, I would say simply that that has been the history of all new things from ancient times to the present. In fact there have been instruments constructed on this principle, one of which was exhibited at Vienna. I had hoped to be able to bring to this meeting an indicator embodying the principle referred to, and showing its full operation; but, finding within the last few days that this would be impossible, I had constructed for exhibition to-night an instrument which will explain to you the fundamental principles, leaving the others for description at a future time.



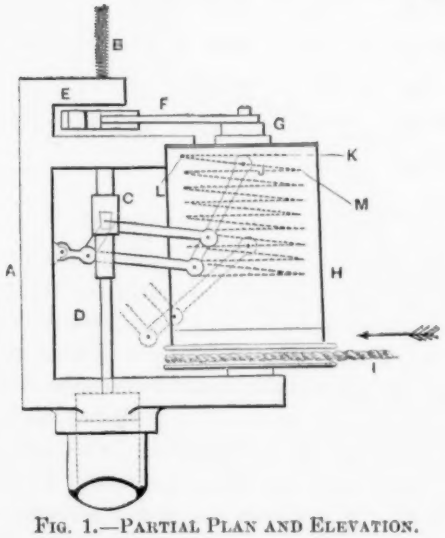


FIG. 1.—PARTIAL PLAN AND ELEVATION.

The instrument, as you will see, contains some of the parts of the ordinary indicator; these were put in to save time; they are quite unsuitable for it, and consequently, the indicator, although taking diagrams, does not take them as perfectly as desirable. It takes them, however, well enough to show the principle of the instru-

ment, and, perhaps, to prove its soundness. Here is a drawing of it (Fig. 1). A complete discussion of the principle and of the whole subject would take too long, so I shall confine myself to-night to the endeavor to make clear to you this principle alone, and should be glad to hear any objections to it which may occur to the gentlemen present. There are certainly some which will apply to the imperfect form of instrument shown.

We can best begin by considering the defects of an ordinary diagram. It is evident to every one having any acquaintance with the subject that when such a diagram is taken on a high-speed engine, instead of getting a normal form, we have, especially at the commencement of the stroke when the steam enters, an oscillation which lasts very often through the whole of the remaining diagram, or at least for some time; in fact, at every sudden change of pressure there must occur such an oscillation, due to momentum of the parts (see Fig. 2). Now I have endeavored to

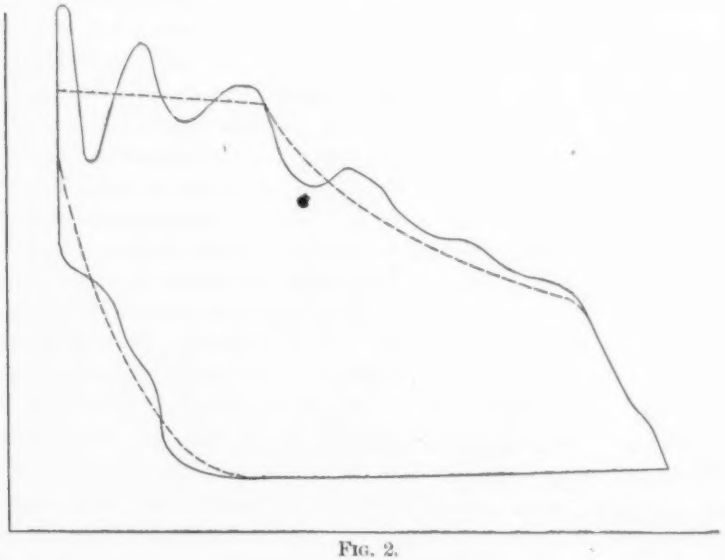


FIG. 2.

correct that upon this principle: Supposing that at any particular part of the vertical stroke of the indicator piston we can stop it and wait until the next stroke, when we will allow it to go on a short distance and stop it again and wait till the succeeding stroke, and then allow it to proceed, and so on. Now, if we can make the parts sufficiently light to act quickly, we can then get an accurate

diagram. How that would be done by this instrument will be explained; but before attempting this, your attention will be called to the diagram itself. This (see Fig. 3) is a diagram taken the day before yesterday on an engine with the cut-off blocked. It had an automatic cut-off, but it was blocked so as to make the expansion constant for a certain time, and it ran as hard as it could, up to 400, when things began to shake so that it could not be run faster. We have here this series of zigzag lines which I call the blank diagram. If the steam is shut off from the indicator, we have nothing further. Each line is made by one stroke of the engine, and if it runs at 400 it would be about three seconds with this instrument, and the diagram is finished. If, however, the cock is open, then instead of going all the way through over the blank diagram, as soon as we get down to the proper pressure, the pencil will begin to make also the diagram itself. Instead of following the 55 lb. horizontal line, it will jump up a short distance, depending on the construction of the instrument, and it will continue up until the pressure on the cylinder falls again to 55 lbs., when it will come back to the 55 lbs. horizontal and finish it out. The pencil will then return to the left side of the diagram on the diagonal line, and the process will be repeated until the card is complete. In Fig. 3 the exact course of the pencil may be traced over the whole card. In this diagram the expansion curve is too far to the right; this fault is due to the inertia of the parts of the indicator, upon which my attachment is placed. To remedy this a certain correction can be made in the card, but with an instrument constructed properly I think this error will be small enough to be neglected.

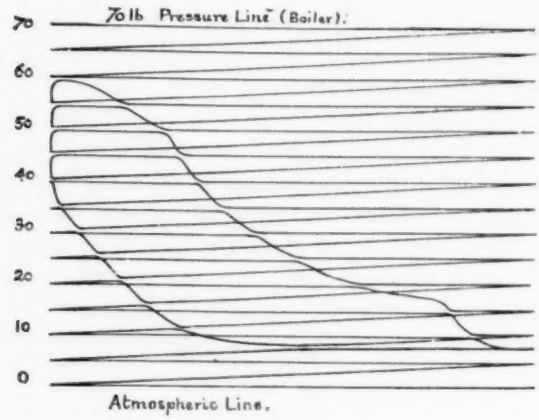


FIG. 3.

In Fig. 1 an ordinary indicator is shown with my attachment. The frame of the instrument is extended up to *e*, and a hole is made through it in which the screw *b* slides freely. This screw

has a nut, *e*, which is confined between the forks of the frame. The lower end of the screw has a forked head, *c*, which embraces the upper end of the piston-rod, and is attached to the same by means of a pin, which passes through holes in both; the hole in the fork is, however, slotted out a little larger than the pin, as will be seen hereafter. If, now, we revolve the nut *e*, the screw will draw up the piston against the spring—the usual spring, not shown, but contained in the indicator cylinder—until we have set the latter at any desired pressure. If this pressure be above the maximum pressure in the engine cylinder, the pin at *c* will remain resting on the bottom of the slot; but if it be below the same, then during any stroke of the engine it will remain there only so long as the cylinder pressure is below that of the spring, and it will jump to the top of the slot when the former exceeds the latter. The slot is made the right length to allow of a jump of 4 or 5 lbs., as shown in Fig. 3. To complete the arrangement we have only to add the pawl *f* and crank *g* mounted on the top of the indicator drum, *h*, and so arranged that during each backward stroke *f* shall revolve *e*, and thus let the screw *b*, with the piston and spring, gradually down. It is clear now that the action will be as follows: Having drawn the spring up to, say 70 lbs. (see Fig. 3), we shall get between that and 60 lbs. simply the blank diagram, of which the diagonal lines are due to the action of the pawl, *f*, after which we shall get the card, as shown.

On the instrument which you have in your hands there is no pawl, but there is another arrangement answering exactly the same purpose. The leverage is the leverage I found on the indicator, and it is very unsuitable. It multiplies too much—it multiplies six times.

This is one of the directions in which improvement has been made in the ordinary indicator, namely, in making the piston move through a short distance, with a large leverage to get cards high enough; and in reducing the height of the cards. A gentleman said to me, "What is wanted are higher cards." In this form we can get as high cards as we please, because the vertical motion is entirely independent of the motion of the piston.

Another trouble comes in, due to momentum: that is, in running the drum of the instrument, which can be avoided in various ways. One of the most necessary things in avoiding it is to run the drum by a string which pulls it in both directions. If a spring is put into the drum, and one string used, it will be stretched a great

deal more during its pull then when it is let back, and a change of phase will result. In the first instrument constructed, I used the ordinary drum, and in running at 430 got a diagram which I will illustrate [illustrating]. In an ordinary diagram a little of that effect might come in without being noticed; it would simply alter the shape of the curve a little, and you would not, perhaps, know that it was not due to some other cause, but in this all of it shows. (The diagram showed a decided change of phase. In a card three inches long this difference was $\frac{3}{32}$ of an inch.) This is an advantageous point in the method, because it enables any change of phase to be detected. In order to avoid that change in this instrument, I used a very light wood for the barrel, pivoted it at both ends, and put in two strings—that is, an endless string connected with the lever. I detected no change of phase whatever, and think, perhaps, up to 500 such an arrangement would be good.

The other improvements that I am attempting may be mentioned briefly. I want to produce a drum of metal, not a wooden drum, that shall not need to be very light, and yet shall run in perfect accord with the engine. I want to make the diagrams all of a certain length and height, so that with the same engine diagrams can be taken with pressures of 40, 50, or 100 lbs, and laid upon each other, and the changes of form seen.

I want also to get rid entirely of springs in the indicator, and think they can be avoided entirely, and the moving parts made lighter. That is a question for experiment.

DISCUSSION.

Mr. Oberlin Smith.—I want to ask Professor Webb if he can tell us anything about an arrangement for measuring the area of these diagrams, which is an improvement on the old methods.

Professor Webb.—That is also another addition which is not on this instrument. Perhaps I should have mentioned it. It is clear that if we measure the lengths of the horizontal lines included in the diagram, and add together those lengths, we have the area of the diagram—which may be done by taking such wheel as a blacksmith uses to measure a tire and running it over these horizontal lines, lifting it up when it leaves the diagram, and returning it when it reënters it. Such an arrangement can be attached to the instrument so that when the pencil rises this wheel will touch an oscillating arc, and you will have a more accurate measurement of the area than can be made in any other way. This motion of the pencil in

rising and falling need not proceed in the direction already indicated; it can be made in a direction perpendicular to the indicator card. When the steam rises above the pressure at which the spring is set, the pencil will be forced against the paper and will draw a line as long as the steam is above that pressure. This makes a diagram consisting of a lot of shading, as if we took an ordinary diagram and shaded the inside of it. It is immaterial, in using the measuring machine, which instrument is put on, because the principle is the same.

Mr. Charles E. Emery.—It is said that there is nothing new under the sun; but I am sure that this is entirely new to me. I feel grateful to Professor Webb for bringing it out. I think this is a principle which can be applied in other directions. As we look at a piece of mechanism of any kind, if we be apt in meeting new problems, we will adapt the features of that piece of mechanism to the new problem. I can see that there will be considerable labor necessary in developing this so that it will to some extent supersede the ordinary indicator, but I must say that I think it encouraging and worthy of effort. The nearest it that I have ever seen in my practice was in using the old Stillman-Allen indicator. We found, for instance, in the navy during the war, running at the high speed we had on gunboats, with a good deal of lead on the valves, the pencil would jump very high at the beginning of the stroke, and distort the diagram throughout, and I have frequently known a very good diagram to be obtained with a block of wood steadied so that the piston-rod would strike it at the right height—the diagrams, in fact, resembling very much those we get with Richards' indicator. That is the same principle applied only to the initial pressure. This is the application throughout the stroke, and really I think it will be brought to such a state of perfection that it will be of use to all, so that most of those who make a specialty of using indicators will want at least one instrument of this kind.

As one having had some experience with many mechanical devices—but as I am getting older, I dislike to go into intricate matters more than I did when younger—I would suggest that perhaps it is best not to put too many things on the instrument. Some of the details suggested here have already been tried, and difficulty found with them. For instance the form of parallel motion is one that Mr. Richards took hold of and abandoned. That of course has nothing to do with the principle. By the plan of simply

carrying up the piston and putting the pencil at the top directly in line with the piston, very good diagrams were got with naval engines at high speeds and initial pressures. Perhaps it is sufficient in this case to use no levers at all, and simply use a spring.

In regard to some of the suggestions that improvements were necessary, my experience would hardly warrant trying to get all cards of the same height. If there is any thing I dislike in the practice of young gentlemen in taking diagrams, it is their tendency to use a light spring so as to get a diagram of pretty good height. I have always insisted that they should use a 40-pound spring for everything. At once the card becomes an indication to the eye of the pressure of the cylinder. If a 40-pound spring is carried at every pressure, it is as accurate at 20 pounds as at 80. I think from one who has taken thousands and thousands of cards in his younger days, this suggestion may perhaps come with some force. Many starting in the use of the indicator are apt to get the cards too long for the barrel, when by allowing a little more leeway for stretch of string, etc., they can get a card which will keep its place on the barrel; this is a matter, however, that does not affect the present case.

Mr. Holloway.—I would like to ask the Professor if he has used this instrument on an engine on which the load varied very greatly indeed. Of course to get a card requires some dozen or more revolutions of the engine, as I understand it. What would be the effect if the engine had a variable load, and what sort of a card would it make working at full stroke part of the time and quarter stroke part of the time?

Professor Webb.—The curves would not join and form a continuous curve. Where the cut-off is automatic, the instrument would give parts of several ordinary cards, and the curve would not be continuous.

With reference to the remarks made by Mr. Emery, I agree with him entirely, although there is something more with regard to the height of the card than I mentioned. With reference to the pencil running directly up—that is the point in this indicator which I mentioned as being unfavorable; it multiplies six times, which is too much. In this form there is no reason why the spring should not be a long spring, and have a large amount of motion. There is no advantage gained in restricting the spring.

Mr. Oberlin Smith.—I would ask Professor Webb why it is not better in all cases to allow the pencil to approach and rest on the

paper so as to make a more definite diagram—whether there are any difficulties in the practical construction of an instrument in that form, on account of which it would not be better always to do that rather than to have the pencil jump up and down on the face of the diagram?

Professor Webb.—If the pencil rises and falls while it is in contact with the poper, the whole curve it makes can be seen. If the pencil is above the paper, and goes to meet the paper, then its distance from the paper must be constant and very small. I think perhaps it would be the better way; but I have made the instrument in both forms.

PART II.

PROCEEDINGS

OF THE

CLEVELAND MEETING,

JUNE, 1883.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

PROCEEDINGS OF THE CLEVELAND MEETING.

Local Committee of Arrangements.—J. F. Holloway, *Chairman;* C. F. Brush, W. M. Barr, Ambrose Swasey, N. S. Possons, W. H. Thompson, F. H. Richards, S. T. Wellman, E. H. Martin, John Walker, W. R. Warner, J. D. Cox, Jr.

Executive Committee.—S. T. Wellman, Ambrose Swasey, J. F. Holloway, J. D. Cox, Jr.

The sessions of the Cleveland meeting were held in the rooms of the Vocal Society, in the City Hall. The opening session was held at 8 P. M., on Tuesday, June 12th. The names of the following members of the Society appeared on the Secretary's register:

Carl Angström.....Worcester, Mass.
Wm. M. Barr.....Cleveland, O.
Stephen W. Baldwin.....New York City.
Wm. J. Baldwin..... " "
J. Sellers Bancroft.....Philadelphia, Pa.
Chas. A. Bauer.....Springfield, O.
Alfred Betts.....Wilmington, Del.
Henry L. Binsse.....New York City.
Wm. H. Bone.....Cleveland, O.
Chas. F. Brush.....Cleveland, O.
J. H. Burnett.....New York City.
Thos. W. Capen.....Stamford, Conn.
Aug. W. Colwell.....New York City.
C. C. Collins.....Erie, Pa.
Geo. N. Comly.....Wilmington, Del.
J. D. Cox, Jr.....Cleveland, O.
W. F. Durfee.....Bridgeport, Conn.
Ezra Fawcett.....Alliance, O.
Rimmon C. Fay.....Hopedale, Mass.
C. M. Giddings.....Massillon, O.
Wm. E. Good.....Reading, Pa.
John J. Grant.....Flushing, N. Y.
Homer Hamilton.....Youngstown, O.
S. Ashton Hand.....Toughkenamon, Pa.
F. F. Hemenway.....New York City.
G. C. Henning.....Pittsburgh, Pa.
Wm. Hewitt.....Trenton, N. J.
J F. Holloway.....Cleveland, O.

F. R. Hutton, *Secretary*.....New York City.
Gustav Kaffenberger.....Hamilton, O.
Wm. Kent.....Pittsburgh, Pa.
Charles Kirchhoff, Jr.....New York City.
Frank E. Kirby.....Detroit, Mich.
J. S. Lane.....Akron, O.
E. D. Leavitt, Jr., *President*.....Cambridgeport, Mass.
W. Barnet Le Van.....Philadelphia, Pa.
Edwin H. Martin.....Cleveland, O.
Geo. W. Maynard.....New York City.
Alex. Miller..... " "
T. R. Morgan, Sr.....Alliance, O.
Joseph Morgan, Jr.....Johnstown, Pa.
Wm. H. Odell.....Syracuse, N. Y.
Geo. E. Palmer.....Chicago, Ill.
Walter E. Parker.....Lawrence, Mass.
Edward H. Parks.....Providence, R. I.
J. F. Parkhurst.....Cleveland, O.
Wm E. Partridge.....New York City.
Franklin Phillips.....Newark, N. J.
Thos. R. Pickering.....Portland, Conn.
N. S. Possons.....Cleveland, O.
Francis A. Pratt.....Hartford, Conn.
Thos. Whiteside Rae.....New York City.
Francis H. Richards.....Cleveland, O.
Luther A. Roby.....Cleveland, O.
S. W. Robinson.....Columbus, O.
A. Wells Robinson.....Montreal, Can.
John B. Root.....Greenpoint, N. Y.
Olin Scott.....Bennington, Vt.
Oberlin Smith.....Bridgeton, N. J.
Jesse M. Smith.....Detroit, Mich.
John E. Sweet.....Syracuse, N. Y.
Ambrose Swasey.....Cleveland, O.
Charles T. Thompson.....Philadelphia, Pa.
John Walker.....Cleveland, O.
W. R. Warner..... " "
W. O. Webber.....Lawrence, Mass.
J. Burkitt Webb.....Ithaca, N. Y.
W. H. Weightman.....New York City.
S. T. Wellman.....Cleveland, O.
Edward Weston.....Newark, N. J.
Jerome Wheelock.....Worcester, Mass.
Joseph J. White.....Philadelphia, Pa.
S. B. Whiting.....Pottsville, Pa.
J. R. Williams.....Pittsburgh, Pa.
Wm. C. Williamson.....Philadelphia, Pa.
C. J. H. Woodbury.....Boston, Mass.
C. C. Worthington.....New York City.

As invited guests of the Society, were present Messrs. H. M

Boies, J. W. Cole, R. C. Carpenter, and Messrs. Hewitt, Miller, Hutton, and many others.

Mr. Holloway called the Convention to order, and introduced Mayor JOHN H. FARLEY, of Cleveland, who delivered the following address of welcome:

Gentlemen of the Society of Mechanical Engineers:

Somewhat like yourselves, I am unused to this kind of work, so that on this occasion you will excuse me if I work from a templet. (Laughter.)

Gentlemen: Members of the American Society of Mechanical Engineers:—On behalf of the citizens of Cleveland I have the honor of extending to you a cordial welcome. The presence in our city of so many eminent students in that most useful branch of science—mechanics—is a great compliment to Cleveland, a compliment for which, as the representative of the city, I heartily thank you. The selection of Cleveland as the place of this meeting is a compliment not altogether undeserved, because there are few cities in the United States that can more fully appreciate the grand results attained from the high state of perfection in mechanics, that mixed science which you profess and so ably represent. Our citizens will undoubtedly use every effort to reciprocate the honor you pay them, by making your stay among us as agreeable and pleasant to yourselves as the interchange of views by the members of your Society must be beneficial to mankind in general.

You will find in Cleveland many institutions which will repay a visit of the student concerned in the working of metals, and in the various uses they bear to the economy of science, and the correlation and application of natural force to the general utility of man.

As mechanical engineering is the great impulse of commerce and civilization, hemmed in by no narrow lines of code ethics, limited only by the laws of natural philosophy, your coming together in fraternal fellowship must result in stimulating study in the sciences of nature and force. Hoping that nothing will occur to mar your deliberations, and trusting that our citizens, and our manufacturers in particular, will do all in their power to aid you, as I know they will, and to make you comfortable, I again welcome and thank you. (Applause.)

The President, replying to Mayor Farley's address of welcome, said:

Your Honor: On behalf of the Society which I represent, I thank you most heartily for your kind words of welcome. When it was announced that the meeting of the Society would be held in Cleveland, it was received with very general satisfaction, for we all had a desire to see the goodly city, the fame of which was in our ears; and our eyes have been gladdened by the sight. As you know, we are all a body of busy men; we are not given to much talk, and we prefer that our eloquence should be in deeds rather than words. Again I thank you. (Applause.)

Mr. J. F. Holloway, of Cleveland, O., then read his paper on the "Marine Engine of the Lakes, and a Device for Getting them off their Centers." He prefaced it with the following pleasant words:

Mr. Holloway.—Mr. President, I have been called upon to read my paper, and to show my little machine thus early in the evening for the purpose, I presume, of assisting in getting the business of this Society under way, and off its center.

I suppose it is true that large Engineering Societies, like large engines (I mean, of course, upright societies, and upright engines) are inclined, during long intervals of rest, to settle down on the lower center; and that it is necessary to "pry them off," before they will "go ahead." If with my little machine, I shall be able to do that much, I have no doubt that the papers that are to follow, will keep thought and discussion in motion, greatly to our pleasure, as well as to our profit.

No discussion followed the paper.

In the absence of the author, a paper by Mr. Howell Green, of Jeanesville, Pa., on the "History and Development of the Winding and Pumping Machinery of the Anthracite Coal Regions," was next read by the Secretary and elicited no discussion.

The next paper was by Mr. G. N. Comly, on "Economy in Lubrication of Machinery."

Following the reading of Mr. G. N. Comly's paper, the President said:

Discussion on this paper is in order, and the Chair hopes that there will be some discussion. It seems as though Mr. Holloway did not get the Society "off the center" and it needs "lubrication," which I suppose will come after awhile, and if we can run without "dry boxes" I hope there will be something said.

Discussion followed, in which Messrs. Grant and Woodbury took part.

After the conclusion of Mr. Woodbury's remarks, arose

The President.—The Chair regrets that it is necessary to close this discussion, as it is nearly time to "lubricate." (Laughter.) Mr. Holloway has an announcement to make.

Mr. Holloway.—Mr. President, I referred awhile ago to the difficulties sometimes met in starting the business for which we gather together. There is, however, another, and, as I think, important feature of our meetings which I would be glad to see started and under way as soon as possible. I refer to the social and friendly acquaintance and intercourse of the members, both new and old. I am sorry to say that I have no invention to lay before you for producing that result; but your Local Committee, who, I fancy, have had a good deal of experience in prying over engines with a bar under the arm of the fly wheel over a short bight, have been getting up an arrangement which they hope will serve as a "starter." (Laughter.) They desire to say while they have no bar on which to lay your arm, that if you will step into the next room they will furnish the "bite" (great laughter), or "bait." (Laughter,) I would move, then, that we take a recess and give their contrivance a trial.

Before putting the matter to vote, Mr. President, I would like to add a word or two more. It has been said that "too many cooks spoil the broth;" but I have not heard it said that too many engineers spoil having a good time. So the Local Committee has invited the Civil Engineers' Club of Cleveland to join us in this meeting, and in looking over this room I think we have just enough engineers to have a good time; and in order that you may know each other perfectly well, I take pleasure in introducing to you, gentlemen of the blue ribbons, the gentlemen of the white ribbons. (Applause and laughter.)

Mr. Grant.—I understood Mr. Holloway to say that we have no bar here. I think we have a Barr already belonging to the Society. (Laughter.)

Mr. Holloway.—Well, you can't get him under your arm. (Great laughter, and calls for Mr. Barr.)

Mr. Barr.—Mr. President, I don't know who is responsible for getting me into this scrape. It looks very much like a put-up job. (Laughter.) I suspect that Mr. Holloway has had something to do with it. Of course, you all understand from what Mr. Hollo-

way and others have said that we have endeavored to do our whole duty, knowing that this is the first time that the mechanical engineers have visited Cleveland, and in the natural order of things it will probably be some time before you get here again. We have not done very much; we have not elaborated very much the little that we have done; but we have endeavored to do the best that we could in order to make your stay here pleasant and agreeable; and not only for the engineers themselves, but I understand that the ladies of Cleveland have interested themselves and will take care of the visiting ladies, and whatever shall be left undone will not be through negligence at all, but simply because we did not exactly understand your needs or your desires.

Now, in regard to what Mr. Holloway has had to say in regard to the "bar" and the "bight," I can only say that this is the Barr and I suppose that he is now ready to present the bite. (Laughter and applause.)

The President.—The Chair would like to announce that the first paper at the morning session will be by Mr. W. F. Durfee, on "Balanced Vertical Engines." The Society will now adjourn for the "bite."

The Society then adjourned to the adjoining room, where a supper had been prepared by the Committee, which was fully enjoyed.

MORNING SESSION.

WEDNESDAY, JUNE 13TH, 10.30 A. M., IN CITY HALL.

The session of Wednesday morning, June 13th, was called to order in the City Hall at 10.30, for the transaction of business.

On motion of Mr. Durfee the reading of the minutes of the last meeting was dispensed with.

The President made a brief statement to the Society of the business done by the Council since the November meeting.

The Council has held meetings for transaction of business on November 24th, February 15th, April 5th, May 4th, and June 1st. The attendance at the meetings has been large at all sessions. The earliest matter acted on by the Council was the election of the Secretary for the current year. The Council appointed a special committee to nominate a Secretary, and the report of these gentlemen, after prolonged investigation of the qualifications of several

candidates, coupled with careful inquiry on the part of all the members of the Council, resulted in the unanimous election of Mr. F. R. Hutton, of New York, who has now filled the office since March 1st.

On April 5th, the accompanying resolutions were prepared in reference to the death of Mr. Peter Cooper, an honorary member of this Society, who had just passed away. The resolutions, signed by the President and Secretary, were sent to Mr. Cooper's family:

Whereas, In the death of Mr. Peter Cooper, one of the Honorary Members of the A. S. M. E., that Society has sustained a signal loss; and,

Whereas, Mr. Cooper had so identified himself with the progress and extension of applied science in this country as to call for the warmest recognition of every engineer: be it

Resolved, That we unite in expressing our gratitude for such a life as he was permitted to live: for its lessons of uprightness and integrity, for its example of usefulness to humanity and for its benefits to his city and to the country. Especially would we recognize the great benefit and help which he rendered to applied science, both through the schools of the Cooper Union and by the ever-ready assistance tendered to those trying to enter the paths of learning.

Resolved, That we express our recognition of the providential care which has so long preserved in activity the hand which fostered the great educational institution which it had founded.

Resolved, That we feel that in the death of Mr. Cooper there has passed away one of the pioneer spirits in the development of mechanical engineering as applied to railroad problems in this country. His successful experiments in the design and test of the locomotive engine were conclusive in settling the question of its future usefulness.

Resolved, That we recognize the advantages due to the early efforts of Mr. Cooper in the development of the manufacture of iron for structural purposes.

Resolved, That while we unite with the public expressions of loss in the death of Mr. Cooper, we also tender our sincere sympathy to those to whom it comes as a sore personal bereavement.

Resolved, That a copy of these Resolutions be sent to the family of Mr. Cooper, and entered on the minutes of the Society.

The matter of the revision of rules, in accordance with the Society's resolution passed in November, has received careful consideration from the Council. The president has appointed, with the concurrence of the Council, the following members as a committee of revision:

W. P. Trowbridge, Coleman Sellers, John E. Sweet, C. J. H. Woodbury and J. C. Bayles.

The committee for nominating officers for the coming year has also been appointed with the concurrence of the Council. It consists of Washington Jones, John C. Hoadley, H. R. Towne, S. T. Wellman and Irving M. Scott.

The Secretary then read the report of the tellers who canvassed the votes for membership.

Messrs. Chas. E. Emery and C. J. H. Woodbury, appointed tellers by the Council under Article XII of the rules as amended at Hartford, reported, June 1st, the election of the following gentlemen as the result of the ballots sent to the membership:

MEMBERS.

ANGSTROM, CARL, Worcester, Mass.
BENNETT, EDWIN H., Elizabeth, N. J.
BETTS, WILLIAM, Wilmington, Del.
BONE, WM. H., Cleveland, Ohio.
BROWN, ALEXANDER E., Cleveland, Ohio.
BURGDORFF, THEODORE F., Washington, D. C.
CAPEN, THOMAS WELLS, Stamford, Conn.
CLARKE, DAVID, Hazleton, Pa.
CUMMER, F. D., Cleveland, Ohio.
DAVISON, HENRY J., N. Y. City.
DEAN, F. W., Cambridge, Mass.
DUDLEY, CHAS. B., Altoona, Penn.
EASTWICK, GEORGE S., New York.
EDSON, JARVIS B., North Adams, Mass.
FAWCETT, EZRA, Alliance, O.
FAY, RIMMON C., Hopedale, Mass.
FITCH, CHAS. H., Stamford, Conn.
GOOD, WM. E., Reading, Pa.
HENNEY, J. B., Stevens Point, Wis.
HILLMAN, GUSTAV, City Island, N. Y.
HOE, ROBERT, JR., New York.
HOLLINGSWORTH, SUMNER, Boston, Mass.
KAFFENBERGER, GUSTAV, Hamilton, Ohio.
KETTELL, CHAS. W., Charlestown, Mass.
LANDRETH, OLIN H., Nashville, Tenn.
LEGGETT, M. D., Cleveland, O.
LIPE, CHAS. E., Syracuse, N. Y.
MILLER, LEBBEUS B., Elizabeth, N. J.
MILLER, LEWIS, Akron, Ohio.
MURRAY, S. W., Milton, Pa.
NORTON, HAROLD P., Washington, D. C.
PALMER, GEO. E., Chicago, Ill.
PARKHURST, JOHN F., Cleveland, O.
PITKIN, JULIAN H., Canton, Ohio.
ROBINSON, A. WELLS, Montreal, Canada.
ROBY, LUTHER A., Cleveland, Ohio.
SCHEFFLER, F. A., Paterson, N. J.
SCOTT, OLIN, Bennington, Vt.
SELEY, CHAS. A., St. Paul, Minn.
SINCLAIR, ANGUS, Cedar Rapids, Ia.
SMITH, JESSE M., Detroit, Mich.

STEARNS, THOMAS B., New York City.
STILLMAN, OSCAR B., Boston, Mass.
STRATTON, E. PLATT, College Point, Long Island, N. Y.
SWAIN, JOHN D., Nashua, N. H.
THOMAS, SAMUEL, Catasauqua, Pa.
VENABLES, JOHN HAMSON, Toronto, Can.
WATTS, GEORGE W., Scranton, Pa.
WEBSTER, HOSEA, JR., Brooklyn, N. Y.
WHEELER, HERBERT A., St. Louis, Mo.
WILLIAMS, J. R., Pittsburgh, Pa.
WILLSON, FREDERIC N., Princeton, N. J.
WOODS, ARTHUR T., Washington, D. C.
ZANE, ABRAHAM V., Washington, D. C.

JUNIOR.

CONANT, THOS. P., New York.

ASSOCIATE.

EVANS, EDWIN T., Buffalo, N. Y.

PROMOTION TO MEMBERSHIP.

HOLLERITH, HERMAN, JUNIOR, A. S. M. E., Boston, Mass.

The President.—It will be seen that the total number of members elected was 54. There was also one junior, one associate, and one promotion. It will be interesting to note here the growth of the Society. In January, 1883, the number of members was 357; additions to this date number 56, making a total membership of 413. The previous yearly additions, at two or three meetings, have been but 60 per annum.

It should be stated here that the Council having neglected to record their names as seconders on the applications of several gentlemen duly proposed, from personal knowledge, the Secretary was directed to add the names of Messrs. Leavitt, Emery, Trowbridge, and Woodbury as may be necessary to bring out all due conformity to the rules.

The next matter is a Report from the Treasurer, which the Secretary will read.

The Secretary then read the following report:

TREASURER'S REPORT

OF AMERICAN SOCIETY OF MECHANICAL ENGINEERS, JUNE 11, 1883.

1882.		
Nov. 2.	Balance on hand	$7 58
" 30.	Receipts during this month	1,806 46
Dec. 31.	" " "	469 54

1883.	Amount brought forward	$2,283 58	
Jan. 31.	Receipts during this month	323 96	
Feb. 28.	" " "	417 72	
Mar. 31.	" " "	436 33	
Apl. 30.	" " "	81 40	
May 31.	" " "	290 28	
1882.			
Nov. 30.	Disbursements during this month		384 10
Dec. 30.	" " "		1,815 46
1883.			
Jan. 31.	" " "		182 00
Feb. 28.	" " "		257 53
Mar. 31.	" " "		518 53
Apl. 30.	" " "		250 46
May 31.	" " "		378 07
	Balance, June 1st		47 12
		$3,833 27	$3,833 27

Since June 1st there has been received thirty-one and $\frac{40}{100}$ dollars, thus making balance of cash on hand at this date seventy-eight and $\frac{52}{100}$ dollars ($78.52).

There is still one U. S. Government Bond of the face value of one thousand dollars, held as an invested fund.

There are unpaid audited bills in my hands amounting to three hundred and sixty-three and $\frac{66}{100}$ dollars (363\frac{66}{100}$), a portion of which is for services of the Secretary of the Society. There is also due the Treasurer the sum of one hundred and fifty dollars ($150) for clerk hire to June 7.

There is due from the membership at this date for initiation fees and annual dues the sum of eight hundred and thirty-nine dollars ($839).

All of which is respectfully submitted.

CHAS. W. COPELAND,
Treasurer.

The President.—The next matter of business is a statement from the Publication Committee; if Mr. Stirling, its chairman, is present, he will please read it. If not, the Secretary will read it.

The Secretary.—The Secretary will simply make a verbal statement that Volume III., which is the complete proceedings and transactions of the Philadelphia meeting of April, 1882, will be sent to the membership next week; that Part 1st of Vol. IV. which is the proceedings of last November, can be sent to the membership in a few weeks' time if desired. The volume is entirely completed; it

simply remains to be bound according to the wishes expressed by the membership to the Secretary's office. It would seem preferable in most cases to delay the first part at this late date until the proceedings of this meeting can be bound up with it. The reprinted papers from the New York meeting of 1883 will be sent out very shortly.

After the conclusion of the business matters, the President announced the paper by Mr. W. F. Durfee, of Bridgeport, Conn., on "A Balanced Vertical Engine." The discussion was by Messrs. Henning, Scott, Le Van, Webb, Comly, Hamilton, W. J. Baldwin, Sweet, and Leavitt.

At the close of the discussion, the President said: If there is no further discussion on this paper, I will call for a paper by Mr. W. E. Ward, of Portchester, N.Y., on "Beton in Combination with Iron as a Building Material." Mr. Woodbury has kindly consented to read this paper, Mr. Ward being detained by the illness of his business partner. Mr. Woodbury then read the paper, and Messrs. Weightman, Root, Comly, and Thompson took part in the discussion.

At the close of the debate the President announced the paper by Mr. Towne, of Stamford, Con., which was read by Mr. Capen.

Mr. Morgan, of Alliance, gave it discussion until the hour of recess.

AFTERNOON SESSION,

June 13th, 2.30 p.m., in City Hall.

Society called to order by the President.

The President.—Before continuing the discussion on Mr. Towne's paper, the Chair desires to remark that he trusts that the members will see the necessity of confining themselves to the intrinsic merits of the subject under discussion. We are apt a little, all of us, to be prejudiced in favor of our own particular hobby-horse, and while we wish to get at the merits of all specific devices, the great thing is to get at the truth of the subject. We all know that there are a great many different ways of accomplishing a given object. It is possible that there may be one best way, though in our experience we have often seen two. I remember an old engineer who said he wished there was only one way to do a thing, it would save him a lot of time. (Laughter.)

I trust in the discussion this afternoon, that view will prevail—that we shall have the advantage of the experience of those who are familiar with the subject, and that they will not confine themselves to any specific device as being the best, but give us the merits and let us as a body judge. (Applause.)

The discussion on Mr. Towne's paper was continued by Messrs. Durfee, Walker, Collins, O. Smith, Capen and Morgan.

A paper by Mr. G. W. Maynard, of New York, on the "Bower-Barff" Process, was next read, eliciting discussion from Messrs. Henning, O. Smith, Partridge and Hand.

The paper by Mr. William J. Baldwin, of New York, on "Standard Cast-iron Fittings" was discussed by Messrs. Barr, Le Van, Walker and Grant.

A paper by Mr. William Kent, of Pittsburgh, on the "Evaporative Value of Bituminous Coals," elicited discussion by Mr. Le Van.

Mr. C. C. Collins, of Erie, Pa., read a paper on "Balanced Valves;" and Prof. Webb, of Ithaca, N. Y., presented a paper, illustrated by models, upon "Reuleaux's Kinematic Models." The models were kindly loaned by the Trustees of Cornell University from their collections.

After Prof. Webb had read his paper,

The President.—As the hour for adjournment is close at hand, we shall hardly have time thoroughly to discuss this paper. I do not know who among us would be able to discuss it very thoroughly unless he has followed the subject very closely, as Prof. Webb has.

Mr. Holloway then made an announcement as to the excursion of Thursday, and in closing said: "I have a piece of very excellent news which I am sure you will very heartily enjoy. I have a telegram dated Hoboken, N. J., June 13th:

"'The Stevens Institute of Technology confers the Honorary Degree of Doctor of Engineering on President Leavitt at its Commencement.

"'(Signed) R. H. Thurston.'"

(Prolonged applause.)

The President.—Gentlemen, there have been Doctors of Medicine and Doctors of Divinity in our family, but this is the first instance, I believe, of any degree of this sort, and I suppose I must thank the Society for electing me to this office for the degree; and I do most heartily thank you, and trust that I shall be worthy of it as far as in my power. I certainly shall try to be. (Applause.)

The Society then adjourned.

In the evening, at the Opera House, the members attended a reception tendered them by the citizens of Cleveland. The Opera House, kindly tendered by Mr. M. A. Hanna, was handsomely draped, and was filled with a very hospitable throng. Everything was done to make the visitors feel at home; the music was very enjoyable, both orchestral and vocal, and a collation was served later in the evening.

Thursday, June 14th, was devoted to excursions.

By the kindness of Mr. R. F. Smith, Assistant Manager of the Cleveland and Pittsburgh R. R., a special train was put at the service of the Society. It left the Union Depot at 9.15 A. M., carrying over 150 of the members and their friends. The first point visited was the Otis Iron and Steel Works, where, under the guidance of Mr. Charles A. Otis and Mr. S. T. Wellman, the open hearth furnaces and rolling plant were inspected. Special interest centered around the plate mill and the devices for charging the rotary puddler. Thence the train proceeded to the Cleveland City Forge and Iron Co., where, piloted by Messrs. Coe and Ely, the members saw shaft forging by helve hammers, and the special forging of coupling links. At the Cummer Engine Works, guided by Messrs. Cummer and Barr, interest centered around the special tools for spacing stud-holes in flanges and the construction of the horizontal governor. Thorough inspection was next allowed of the Union Steel Screw Works, by the courtesy of Messrs. Fayette Brown and Bidwell. At the Brush Electric Works, Messrs. Stockley and Possons received the members as they alighted from the train, and showed every attention to their guests. At the shop of Messrs. Warner & Swasey, interest centered around the running gear for a 40-foot observatory dome, which, when fully loaded, could be set revolving by a pull of 30 lbs. The special device for planing segments was then noticed. After a visit to the very extensive malleable iron foundry of the Cleveland Malleable Iron Works, the party were taken out to Newburg, and were received at the gate of the Cleveland Rolling Mill. Under the leadership of Messrs. Chisholm, Walker and Martin, the successive heating furnaces, the Bessemer steel and open hearth plants, and the Blooming mill were visited, and especial interest was shown in the continuous wire-rod mill. After visiting the mill for shapes, the Society was escorted to a luncheon served in a large hall of the town. Not a little merriment followed remarks complimentary to the "Martin" process, through which its guide had carried the Society, involving the abundant use of "plate."

After luncheon, the excursionists boarded a train tendered by Mr. J. M. Ferris, of the N. Y. P. and O. R. R., and visited the new Central Furnace of the Rolling Mill Co. This furnace is now producing an average of 1,500 tons a week, and the members were privileged to arrive there in time to witness one of their large casts. Thence visits were paid to the Ore Docks, where Mr. A. E. Brown's Hoisting and Conveying Plants were shown in operation. A visit to the two pump-houses of the Water Works showed the members the Cornish and Worthington pumps for supplying the city, and after leaving their train, the members were escorted to examine the viaduct and its swing bridge. At that point the party separated.

During the time of the visits to the shops, etc., Cleveland ladies had accompanied the goodly number of lady visitors in a pleasant drive to and through the Lake View Cemetery, the grounds of Adelbert College, and the private park of J. H. Wade, Esq. They returned delighted with the city, their hosts and their drive.

EVENING SESSION.

JULY 14TH, 8 P. M., IN CITY HALL.

The session of Thursday evening, June 14, was called to order a few moments after eight o'clock by Prof. Sweet, in the following words:

GENTLEMEN:—In the absence of the President, it has devolved on me to call the meeting to order, as the Secretary thinks it is best to go on. The first business will be a paper by Mr. Oberlin Smith, of Bridgeton, N. J., on "Spiral Springs: Compressive and Tensile."

Mr. Oberlin Smith then read his paper and the discussion upon it was participated in by Messrs. Robinson, F. H. Richards, Webb, Grant, Pickering, and Leavitt. After the President had returned to the chair, Mr. G. C. Henning, of Pittsburgh, Pa., read a paper entitled, "Some Notes on Steel," and Messrs. Leavitt and Le Van took part in the discussion which followed. Mr. W. F. Durfee, of Bridgeport, Conn., then read a paper on "Machinery for Manœuvering Clutch Couplings," which was illustrated with a handsome colored drawing. Mr. Walker took part in the discussion which followed.

The hour for adjournment having nearly arrived, the Secretary, in the absence or by the wish of the authors, read the following papers by title:

Julius S. Hornig, Jersey City, N. J.: "Economy in Subdivision in Installation and Operation of Machinery at varying demand."

Gram Curtis, New York: "Remarks on the Ordinary Form of Bessemer Ingot Cranes."

John E. Sweet, Syracuse, N. Y.: "On a New Method of Constructing a Crank Shaft."

R. H. Thurston, Hoboken, N. J.: "Note on the Water Hammer in Steam Pipes," with discussions to accompany the paper by Messrs. W. P. Trowbridge and Chas. E. Emery.

S. S. and W. O. Webber, Lawrence, Mass.: "A New Form of Balance Dynamometer."

T. W. Rae, New York: "Some of the Mechanism employed in Multiplex Telegraphy."

John E. Sweet, Syracuse, N. Y.: "On a new Method of Casting Flange Pipe."

R. H. Thurston, Hoboken, N. J.: "Note on the Effect of Prolonged Stress on Iron."

After the reading of the above papers by title, the following resolutions were offered, duly seconded, and carried:

By Mr. John B. Root:

Resolved, That the thanks of the American Society of Mechanical Engineers are due to J. H. Farley, Esq., and to the citizens and ladies of Cleveland for the cordial welcome and kind treatment extended to them on the occasion of their visit to the city of Cleveland, and especially are the thanks of the Society due for the great pleasure accorded them on the occasion of the reception of June 13th.

By Mr. W. E. Partridge:

Resolved, That the thanks of the Society are due and hereby tendered to M. A. Hanna, Esq., for the use of his Opera House, and for personal services on the occasion of the Citizens' Reception, on June 13th, and for his assistance in making that occasion one of great pleasure.

By Mr. F. A. Pratt:

Resolved, That the thanks of the American Society of Mechanical Engineers are due to the Otis Iron and Steel Co., Cleveland City Forge and Iron Co., Cummer Engine Works, Union Steel Screw Works, Brush Electric Works, Warner & Swasey, Cleveland Malleable Iron Works, Cleveland Rolling Mill Co., at their mill and furnace, and to Alexander Brown, Esq., and others representing the Ore Docks, for courtesies extended during the Society's visit to their various establishments.

By Mr. C. J. H. Woodbury:

To R. F. Smith, Esq., Manager, and to the Cleveland and Pittsburgh Railroad Company, and to J. M. Ferris, Esq., Manager New York, Pennsylvania and Ohio Railroad Company, for the use of excursion trains by which the Society of Mechanical Engineers were enabled to visit so many of the manufactories of the city, we desire by this resolution to return our most hearty thanks.

By Mr. W. F. Durfee:

Resolved, That the Society return thanks to the Faculty of Adelbert College and to J. H. Wade, Esq., for the cordial invitation extended to visit that institution; and that the thanks of the Society are also due to the Deering Seamless Barrel Co., to the Cleveland Stained Glass Co., and to many others for invitations to visit their works, and for courtesies shown to individual members during the session.

By Mr. Oberlin Smith:

Resolved, That we tender the thanks of the Society to John Whitelaw, Esq., of the City Water Works, to R. Doty, Esq., Chief Engineer of the Water Works, and to B. F. Morse, Esq., City Engineer, for courtesies shown the Society while visiting the Water Works and the Viaduct.

By Secretary F. R. Hutton:

Resolved, That the thanks of this Society be tendered to the Civil Engineers' Club of Cleveland for its courtesies extended and assistance given, and for their attendance and interest in our sessions.

By Prof. J. B. Webb:

Resolved, Thatthe thanks of the Society are due to the Executive Committee of the local members for the complete arrangements made for our entertainment, and for the most admirable manner in which they have been carried out during the day which has been devoted to excursions, and which has been so much enjoyed by all.

Resolved, That the Secretary be directed to send copies of these resolutions to the gentlemen mentioned.

Mr. Le Van further moved a special vote of thanks to those ladies of Cleveland whose attention to the visiting ladies had given so much pleasure. His motion was duly put and carried.

At the close of these resolutions:

The President.—The Chair desires to remark before adjourning, that we must all regard the days of the Cleveland meeting as red-letter days in our history. (Applause.) I am sure that it is a new departure for the Society. I think we can all congratulate ourselves that we were able to attend the meeting, and I hope we shall make it an example for future meetings.

I have been requested by representatives of various Eastern establishments to ask the members, the Cleveland members and all other members, to be sure and call on them whenever they are in the East, both at our works, offices, and at our various homes, when we shall attempt, in some degree at least—we know that we cannot do it fully—to requite them for their courtesies.

I will say that when it was announced that the meeting would be held in Cleveland, I felt sure from my acquaintance with the local members that it would be a success. But they have gone so far beyond my most sanguine anticipations, that I feel that in addition to the vote of thanks of the Society, I wish to give them my most cordial personal thanks, for it has been a great relief to have everything so pleasant.

Mr. Holloway.—Mr. President, I would like to make an announcement, if it is in order.

The President.—Certainly it is in order. We shall be very glad to hear from Mr. Holloway.

Mr. Holloway.—Mr. Charles Latimer, Chief Engineer of the New York, Pennsylvania & Ohio Railroad, who is, as we Cleveland people know, a very busy gentleman indeed, and who has regretted very much that he has been unable to attend the meetings, and especially regrets that he could not be here to-night, has very kindly sent here some magazines with which he is in some way connected, of which he hopes the members will take a copy. Mr. Latimer has very kindly interested himself, too, in trying to secure for the members of this Association reduced rates of fare to Chicago. He reports that he finds it impossible to do so until next Tuesday. I don't know how you will avail yourselves of them unless you stay till Tuesday, which we shall certainly be very glad to have you do.

There is another feature here which illustrates Mr. Latimer's kindness and forethought. The Road has recently prepared a very elegant map showing the location of coal mines, of the furnaces and of the important stations upon their Road connecting with what is known as the Mahoning Division. Mr. Latimer has very kindly sent here some fifty copies of that map, which he desires to have distributed among members who will be interested in matters of that sort, and at the close of the meeting I shall take great pleasure in distributing them. (Applause.)

The President.—It is very hard for the Chair to ask for a motion to adjourn, after such a pleasant meeting.

Mr. Le Van.—I move we adjourn, Mr. President.

The motion was duly seconded.

After the question was put and carried, Mr. Grant proposed three cheers for the Cleveland members. The three cheers were given with a hearty good-will, and the meeting adjourned.

THE MARINE ENGINES ON THE LAKES, AND A DEVICE FOR GETTING THEM OFF THE DEAD-CENTRES.

BY

J. F. HOLLOWAY, CLEVELAND, O.

THE value of any mechanical device or invention is determined in the end by the necessity there is for its existence. A machine may be very elaborate and ingenious, but if the purpose for which it is created can be accomplished by a simpler and easier method, the complicated machine, no matter how carefully planned, will find no favor.

This being so, it behooves me first to explain the necessity that exists for the device I have to show you, in order that the device itself may find favor in your eyes. The marine engines in use upon the lakes are almost entirely of the inverted direct-acting type—there are, however, a few side-wheel steamers with beam engines still used on the rivers emptying into the lakes, and for short coasting lines. By far the greatest number of these lake engines have single or tandem cylinders connected to a single crank. The next largest number in use are double engines, attached to cranks placed at right angles with each other; while there are a few of the more lately built double engines that have the cranks placed directly opposite each other. While I do not wish to occupy your time in reviewing generally the history of the lake marine engine, it is proper that I should say that it was upon these inland waters that the value of the screw propeller was first recognized as being the best method of propelling vessels by steam. I do not mean that the first propellers used were built here, as they were doubtless first built and used upon the inland canal routes between Philadelphia and New York, but I do mean that while the largest engineering establishments of our country—such as the Allaire, Secor, Novelty, and other large works—were persistently engaged in fitting out ships with beam engines and side-wheels, the engine-builders here in the West were building screw propellers to take the place of the beam engines then in use here. There were even instances where beam engines, that had been superseded here by the more compact and more cheaply run direct-acting propeller

engine, were taken out of vessels and sent East to be used in sea-going steamers!

The early propeller engines were simple high-pressure cylinders, placed on the top of wooden posts, or gallows-frames, which rested upon wooden floor-timbers in the bottom of the hull; and for the class of vessels they were intended to propel, they gave most excellent results. Many an engineer in later times, when he has had an engine hammering and pounding away on iron columns and iron bed-plates, has sighed for the old-time engine with its wooden gallows frame, and which ran so quietly and so smoothly. The conditions under which the marine engine of to-day has arrived at its present proportions are somewhat peculiar, and may perhaps be of some interest to those not familiar with them.

At the first, the marine engine here was not only simple and non-condensing, but it was small as well. Steam cylinders from 16 to 20 inches bore were the rule. The vessels in which they were used ranged from 275 to 350 tons burden. These small boats, with their small engines, were at that time sufficient to accommodate all the business other than that done in sailing vessels. The growth of the country westward, however, soon gave an impetus to vessel building, and for many years there was a sharp rivalry between larger sailing craft and larger propellers. It is only recently that sail vessels may be said to have yielded to the inevitable, and now, as consorts, or tow-barges, very many of them do their sailing at the end of a tow-line, and the day is past when any large-sized vessel, dependent upon sails alone, will be built upon these inland seas.

The small propellers have in their turn been supplanted by steamers of 270 ft. length, 40 ft. beam, 20 ft. depth of hold, and which rate from 1600 to 2200 tons. The little "Puffing Billy" engines, whose snorting exhaust used to awaken the echoes along the heavily timbered shores of these lakes years ago, have now given place to massive, cumbersome, compound engines, which, in addition to the large and heavily laden hulls within which they are placed, often drag behind them one or more equally large and equally heavily loaded sailing vessels, or tow-barges; and, so far as appearances would indicate, they do it without much effort. Unfortunately for both engine builders, as well as vessel builders, while there has been such a large increase in the size of vessels, and in their engines and boilers, there has not been a corresponding increase in the width, and the capacity of the harbors of the lakes, or in the depth of the water at their entrances, or in the

rivers connecting the chain of lakes together. In consequence of this fact, the large increase in the carrying capacity of the present vessels has been obtained mainly by adding to their length and beam, rather than to the depth of the hold. Since the strength of a hull is largely dependent upon the depth of its sides, and since the overhead arches, formerly used, have been found in late years to interfere with loading iron ore and lumber, the difficulty now is to build a hull that shall be strong enough to carry, in addition to its own cargo, the power required for its own propulsion, as well as the power required to tow one or two vessels of the same tonnage behind it. One of the results of putting such powerful machinery into hulls of this description is that the hull being long and comparatively shallow lacks vertical stiffness. It readily responds to the pulsations of the engine, until, at certain speeds where the number of strokes comes into unison with what might be termed the time of vibration, due to the weakness of the hull, the shaking becomes a very serious matter. While this is true of an engine having a single crank, the use of enignes having double cranks placed at right angles does not in the least help the matter, for not only are cranks so placed much more difficult to balance, but they have in addition to the up and down motion another motion which may be called an *athwartship* motion. When the crank-pin sof such an engine are both on one side of the main shaft, they produce a severe side thrust upon the main journal-bearing, opposite them, which tends to push it sidewise. This side strain, on the return stroke of the piston, is, of course, transferred to the other side of the journal-box, and thus these alternating side thrusts added to and merging into the up and down motions, combine and form a sinuous motion much more destructive to the hull than the simple up and down motion first referred to. Of course these difficulties are increased when the engines are to any extent unbalanced, experience having shown that the better all engines are balanced the less will be their influence upon the hull. The first successful attempt to overcome this vibratory action of the engine upon the hull, was made in the construction of the steamship *Amazon*, which was built in the year 1873. The hull of this vessel was in some respects peculiar: it was 240 ft. long, 40 ft. beam and 20 ft. depth of hold. She was propelled by twin screws, and had two stern-posts, and was built without overhead arches. Each wheel was driven by a pair of fore and aft compound engines, but the cranks, instead of being placed, as usual, at right angles with

each other, were placed so as to bring the crank-pins directly opposite each other. These engines made, ordinarily, 75 revolutions per minute, and so well was the labor divided between the two cylinders, and so carefully had the reciprocating parts of the engine been balanced, that the main shaft, instead of being first pounded down on the bottom of the journal and then against its cap, seemed almost to be suspended in the air. The result was that there were no vibratory motions to be transferred to the hull, and it was almost impossible to tell when standing on the bow of the boat, whether the engines were in motion or not. As a better evidence still of the value of this arrangement of the crank shafts of a marine engine, there is an instance of a large propeller, built recently, which had a pair of fore and aft compound engines, coupled to the main shaft in the usual way by cranks placed at right angles with each other. While the construction of the hull of this propeller differed in no way either as to its shape or strength from boats as usually built, it was so severely shaken by the machinery during the first season it was in commission that it was very evident to the owner as well as the crew that it could not long endure such usage. At the close of navigation, the cranks upon the main shaft were so changed as to bring the crank-pins directly opposite to each other, and the result was that the hull no longer suffered from any motion of the engine. I stated previously that by far the greatest number of engines in use on the lakes had single cranks; and I have tried to show that for large vessels which required double engines, the best method was to place the crank-pins of such engines directly opposite to each other. Now, it will be apparent to all that in at least one particular both the single and the double engines will be alike—they will both have the same liability to "catch on the centre," while being worked slowly, in and out of port.

To those familiar with the narrow rivers and the small and crowded harbors into which, and out of which, these large steamers must so frequently be worked, it is a marvel that much more damage is not daily done. The skill required both in the Master, as well as in the Engineer, of these boats, under such circumstances, could not have been obtained except by long and careful training.

At first, the boats and engines were both small and easily handled; the harbors were comparatively unoccupied, and of bridges there were none.

By degrees the boats increased in size and numbers, and numer-

ous bridges were built over the navigable waters, until now it is a difficult as well as a dangerous task to enter many of the harbors on the lakes. Vessels heavily laden are now obliged to move slowly and with great caution while entering or leaving port, and the frequency with which the engines are made to stop, start, back, or go-ahead, renders them quite liable to "catch on the centre." Owing to the crowded condition of the ports, and the numerous bridges to be passed, if an engine is thus, even for a brief time, disabled, there is great danger lest the vessel shall do or receive serious damage before the engine can be started "off its centre," in the usual way—the usual way being to hunt up an assistant or a fireman, and send him below slowly to pinch over the crank-wheel with a pinch-bar—an operation not only slow, but also dangerous.

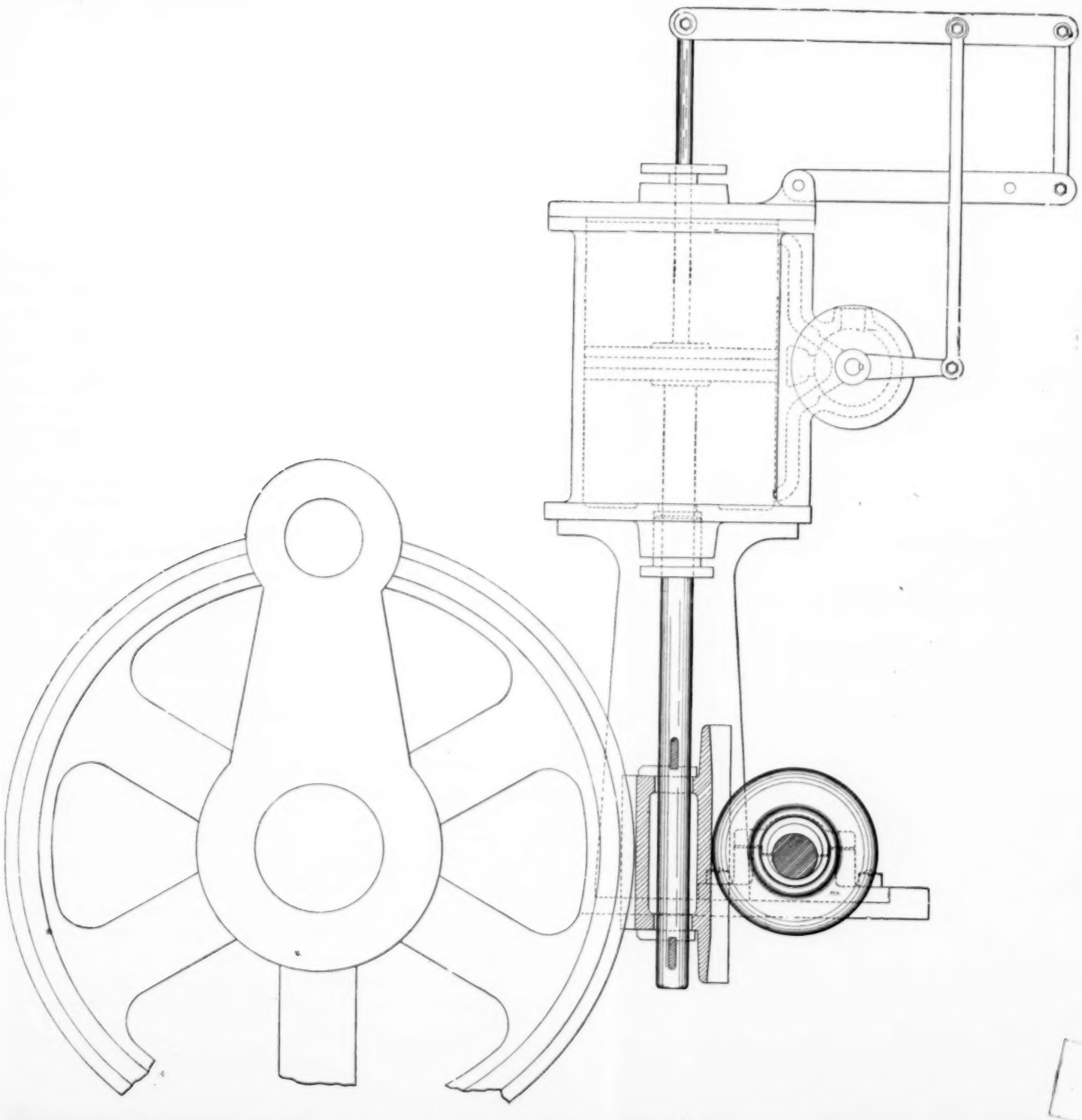
Having, after what has seemed doubtless to you a long time, either skillfully or unskillfully, gotten the marine engine of the lakes upon its centre, my next effort will be to show how best to get it "off the centre," and under weigh again, with the least delay and without danger. The device which I have successfully employed for that purpose, and to which I desire to call your attention, consists of a short-stroke steam cylinder, located in the hold of the vessel, and alongside of the propeller shaft. I place it at the point where the in-board and out-board shafts are coupled together, as the rim of the coupling is very convenient for carrying a portion of the machinery. I place on the coupling flange, or on the shaft, a wheel having on its face a series of V friction grooves. Opposite to this friction wheel, I place either a short segment of a wheel, or a short straight block of iron, which has upon its face a series of V friction grooves corresponding with those on the wheel. This block or segment, as may be most convenient to be used, is connected directly to the piston rod of the short stroke steam cylinder; and it is also so arranged that it may be made to move towards the friction wheel, and to come in close contact with it, by means of an excentric journal, or a similar device.

Now, if in working the main engine forward or back, it becomes caught upon either the upper or lower centre, the valve gear of the engine may be set for turning the engine in the direction wanted, and the throttle-valve may be opened so as to admit steam on the piston if desired. Now, if the block, or segment of the starting engine be brought in close contact with the friction wheel on the propeller shaft, and steam then be admitted to the piston of the starting engine, you will readily understand that the friction

wheel, and the shaft to which it is attached, will be turned a distance equal to the length of the segment or the block. This distance is regulated by the length of stroke of the cylinder of the starting engine, and will be just enough to throw the crank "off the centre."

The main engine will move off at once, having already had its valve gear placed in position, with the throttle-valve open; while the starting engine has pulled or pushed the segment or block out of gear with the friction wheel, and, of course, out of the way, without any further attention from the engineer. The handles for bringing the block or segment into gear with the friction wheel, as well as the handle for admitting steam to either side of the piston of the starting engine, will both be placed conveniently near to where the engineer stands while working the main engines. He is not obliged to leave his place to work the starting engine.

There are a few other matters of detail which would not be, perhaps, of any particular interest. I may say, however, that the starting engine is designed to work either way, and to turn the engine off either centre. If, when it is required for use, the piston should happen to be at the wrong end of the cylinder, the engineer will move the block or segment back from contact with the friction wheel, will make one stroke of the piston without touching the wheel, and will then move the segment or block back in contact again, when the starting engine will be ready to turn the propeller shaft in the direction wanted. This is done with but a very slight loss of time, and without any necessity for calling upon any one for assistance.



HISTORY AND DEVELOPMENT OF WINDING AND PUMPING MACHINERY IN THE ANTHRACITE COAL REGIONS OF PENNSYLVANIA.

BY

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THE anthracite coal-beds of Pennsylvania—(some 15 in number), classified by the color of the ash—may be divided into four divisions. The uppermost group is red ash; second, gray ash; third, white ash; and the fourth, or lowest group, is again red ash. This color of the ashes might seem more of a chemical than a mechanical question, but as it is a tolerably sure criterion of the condition of the water in the mine, as well as of the burning properties of the coal, it was early noticed.

These beds of coal lie at every possible inclination to the horizon, dipping under the surface over 2000 feet (say 1000 feet below the level of the sea), and running up mountains hundreds of feet above the beds of adjacent streams.

The first coal was mined where it was most easily got at, so that in the earlier days of the trade (which commenced about 1820), only drifts or tunnels above water-level, and strippings near the surface, were used to get the coal.

Soon the requirements of the market made it necessary to go into the depths of the earth for coal, and means had to be provided to hoist the same, and to keep the mine clear of water.

The soil in the coal regions is poor, and before mining commenced population was sparse, and the few inhabitants combined hunting, fishing, farming, and lumbering in about equal proportions for a livelihood.

On the influx of strangers, who thronged to the newly opened mines, amongst others there came miners and engineers from England, Scotland, Wales, and Germany, who had seen mining machinery and appliances at home; and here in the New World they constructed engines and pumps. Native ingenuity and the absolute necessities of the situation prompted men to plan and build the contrivances to win the coal. Money and enthusiasm lent their powerful aids, and the ever-increasing sum of human knowledge has made

it possible to show, in the last numbers of the series of mining plants, very handsome examples of the mechanical engineering of the anthracite coal regions. The progress is shown in that series from first to last. Some of the early members are yet standing in obedience to the old law of the survival of the fittest; whilst many of them kindly (though sometimes unkindly) have been consigned to the cupola and heating furnace, where have been transmuted so many darling creations.

Very early in the progress of mining below water-level it was seen that means had to be provided to hoist from 300 to 400 feet at one lift, so as to get space for breasts, to work the coal profitably; and the quantity of water to be raised was found to run into hundreds of gallons per minute. From the first, both slopes and shafts were used. The mine cars in the anthracite regions have always been large, starting in the early days at about 40 cubic feet capacity, and standing now at about 96 feet. The wheels of the cars have been from 12 to 20 inches diameter; 18 inches is now most generally used. The axles have been from 2 to 2¾ inches diameter. The gauge of the mine railroads varies from 30 inches to 48 inches; in a few cases it is 4 feet 8½ inches. At first chains were used for hoisting, and some of the early shafts had hemp ropes. Flat chains, or, rather, three chains side by side, with alternate large and small links, and with blocks of wood through the large link, were tried. These flat chains were wound on flanged spools like a ribbon. Iron and steel bands were used, but the conclusion of the greatest number now is to use iron-wire round ropes. Not that iron-wire ropes are better than steel-wire ropes; but questions of endurance, cost, etc., in relation to wear and weight and work in acid water, have rather been against steel-wire ropes. In a shaft no rope rollers are used, but on a slope—particularly one with varying pitches—the question of a roller to protect the rope is most important. While it has been a vexed question, yet after trial of hundreds of forms and many kinds of material, it seems to be considered that a hardwood roller about 8 inches diameter, truly turned, and kept clean and clear, is the best for ordinary strains. It was soon found out, in using wire ropes, that the life of the rope was much lengthened by making the drums and sheaves of large diameter—the rope must spring around the drums and sheaves, and spring back, and not receive a permanent set.

The first steam engines used for hoisting anthracite coal and pumping the water (and at first they combined both duties) were

single high-pressure engines, with flat bed-plates bolted on wood frames. The steam cylinder would be perhaps 18 inches diameter, with 6 feet stroke. A cast-iron crank-shaft, with perhaps a 10-inch journal, carried the heavy fly-wheel. On the crank-shaft there was a pinion 30 inches diameter, of 3 inches pitch and 12 inches face, which geared into a drum wheel 60 inches diameter, which was just above the pinion. Just under the pinion was the pumping wheel, 8 feet diameter; this pumping wheel had holes in it to receive a pin for working the pump. The drum shaft was of cast-iron, with perhaps an 8-inch journal; its body, as that of most all other shafts then, was octagonal, and the drum-wheel spiders and most everything else were staked and keyed on by the methods of the old millwrights. The drum was from 5 to 8 feet diameter, and about 11 feet long, and was formed of hardwood laggings bolted on spiders. To wind a car 400 feet with a 5-foot drum, the engine would have to make about 48 revolutions, which it was made to do in about one minute. The pumping shaft was also of cast-iron, with perhaps 11-inch journals; and the drum shaft was lifted in and out of gear by a strong wooden lever, one of the pillow blocks being hinged for that purpose. The pump was, of course, near the bottom of the mine, perhaps 400 feet away. It was a lifting pump, 16 inches bore, 7 feet stroke, fitted with a bucket faced with sole leather, the rod of which went through a stuffing-box in a goose-neck, or turn-piece. Up the slope or shaft went a wooden rod, 8 inches square, carried on flanged rollers. The rod was spliced with plates $4'' \times \frac{5}{8}'' \times 10$ feet, and on top of the slope or shaft were one or more rocking bobs, provided with great balance boxes.

The rods connecting the balance bobs to the wheel were $8'' \times 16''$, and were provided with suitable straps, etc.

The valve gear of this engine consisted of two eccentrics and rods with hooks on the ends, which the engine man lifted in and out of gear with his feet, thus leaving his hands free for full control of the slide-valve, which he operated with a long bar. He regulated the quantity of steam for the engine by a throttle of the stovepipe-damper pattern. Thirty years ago such a pumping and hoisting engine was considered first-class, and many of the old fellows are yet at work.

Such an apparatus was subject to many mishaps. With a heavy fly-wheel whirling around, and the slide-valve at the will of the engine man, unnecessary strain could be easily thrown against the engine, and broken cranks and shafts were often the consequence.

Also, if in lifting the drum out of gear it was not securely scotched, the unbalanced end of the chain would fly down the slope or shaft. When it was necessary to connect or disconnect the pump rods, the rocking bobs had to be securely blocked, and sometimes the assistant forgot to take out the last block—and then trouble came.

This state of affairs was much improved by putting up another engine, so that one engine could pump, and the other one could hoist. Next it was discovered that two engines could be attached to the same shaft, at right angles to each other, so that no fly-wheel would be wanted. Yet on some of the first pairs so built, small fly-wheels were put on—probably to verify Darwin's theory of gradual development. The first of these double engines had two eccentric hooks to each engine, making four in all, which the engine man had to lift withlevers. Now he had two engines to handle, and it took a lively man to do it; but since there was little or no fly-wheel, no great danger was incurred. The engine man, therefore, hooked one engine in and started the load with the free engine. These double engines with four hooks did very well. Next, links for valves were introduced, and they are now generally used.

It was found that hoisting and pumping engines in which cog-wheels were used were subject to noise and break-downs, and as the mines went deeper it was found that drums keyed immediately on the crank-shaft of a double engine did the best. This change, of course, involved larger steam cylinders, and in the place of wood-faced drums cast-iron ones were made, which soon led to the use of spiral grooves to keep the ropes from chafing. Still further, these drums were made conical, so that when the heavy load was to be started the small end of the cone did the pulling, whilst the empty car (and cage, if in a shaft) pulled by the large end of the cone on the other side. This arrangement is the best yet tried—and so the hoisting engines stand to-day. These are strongly built double engines on strong stone foundations, with steam cylinders from 20 to 40 inches diameter and stroke from 4 to 6 feet. There are heavy wrought-iron shafts, spiral-grooved cast-iron conical drums, steam brakes and steam reversing gear, with apeliances to prevent over-winding, with safety catches and detaching gear; and, barring waste of steam, the world can show no better hoisting engines than are in the anthracite coal regions of Pennsylvania.

To a mine below water level, the pump, or other appliance to raise water, is of first importance. When man enters nature's great

storehouses in search of wealth, he finds that water is ever ready to dispute his supremacy. Sometimes it is the constant stream, only varying with the season; often there are great quantities stored in the crevices of the rocks. In parts of the anthracite coal regions, the fact has been shown that the first 100 yards down the vein has the most water; the next 100 yards has less, and after that the vein is often perfectly dry. Perhaps the most discouraging situation for a mechanical engineer to be called to in the anthracite coal regions, is to have to provide the remedy for an old drowning mine, where the vein is large, the pitch steep, the top bad, the mine full of fire-damp, the timbers old and rotten, and the water so full of acid that it will eat up a shovel in a night, with the air so close that one can hardly breathe. On these occasions darkness and danger are our companions, and great expense and long delay are our inevitable followers.

The first mining pumps used were of the Cornish pattern—the old drawing lift with an iron bucket faced with leather. This leather was held in place by a wrought-iron or brass ring which nearly fitted the working barrel, and was driven full of wooden pegs. If the working barrel was made of hard iron, and the length of the rod nicely adjusted, so that the leather would come slightly above the bore in the up stroke, and if the water was clean and not acid, and the lift not too heavy—then, this is still the best mining pump ever made. The red ash veins were the first ones worked below water level, and the water in red ash mines will not, as a rule, eat up iron; but when slopes and shafts had to be sunk on the white ash veins, there the lifting pumps would not do. The sulphuric acid in the water ate them up. Some brass working barrels and brass rods were tried, but they were expensive and short-lived. Open-topped force pumps were made, hoping that they could be lubricated and made to stand, but the general conclusion arrived at, about the year 1848, was, that plunger pumps must be tried. Since that time they have been generally used, and the reason of their longer life is that plungers can be lubricated and the corroding action of the acid water lessened. As the first lifting pumps were worked by rods running up to the engine, quite a change in balance boxes occurred when lifting pumps were changed to plungers, and about this time quite a number of double-acting pumps were put in. These pumps, of course, discharged water at each pass of the piston, and had four valves instead of two. About the year 1854 or '55, the Bull engine and pump were introduced.

These did away with cog-wheels for pumping, as the pump rods were fastened to the piston rod of the steam engine. No fly-wheel or crank was necessary on these engines, since the cylinder was made large enough to lift the rods which were made heavy enough to force up the water on their downward stroke.

These engines and pumps have been a real success. They had to be very strong, from the nature of the case. The valve gear is beautiful. It is the result of one hundred years' experience in Cornwall, from whence the idea came. The engine man has to be a man of good judgment, as he deals with very heavy weights. Yet, as regards consumption of steam, the two-valved engine of the anthracite coal region compares very unfavorably with the three-valved Bull engines of Cornwall.

About the year 1860, steam pumps began to be used in the coal mines. The great departure was in bringing the engine and pump together; and from the unfortunate nature of the case, the engine had to be taken down in the mine 500 to 1,000 feet from the boilers. Here commenced another trouble, which is the great loss of the power of the steam so conveyed.

Strange as it may seem, the old war between acid water and pistons and rods had to be fought over again, and the acid water came out ahead with steam pumps, just as it did with lifting pumps.

This paper must be too short to go over all the questions of steam pumps, with their valve movements—positive, isochronal, and steam-moved,—of pumps alternate and reciprocating, with bronze linings, rods and valves; with roomy valve-chambers and easily changed seatings, etc., with air chambers and air lodgments; together with questions of relative size, speed, and portability. Yet I must take time to say, that to pump acid water a plunger seems the best, because it can be protected by grease (in cold water), and the action of a piston on the lining of a pump will even hasten the corroding action of the acid water; that steam carried 500 to 1,000 feet, in pipes ever so well covered, will lose much of its power; that ordinary high pressure steam engines, using such steam and making no use of the principles of expansion, are great wasters of steam; that centrifugal pumps, even with short lifts, will hardly do for acid water; that the introduction of steam into vessels just emptied of cold water seems a return to the days before James Watt; that the ponderous engines of Cornwall, or the splendid examples lately set up at our American water-works, are too costly

for the ever-changing locations incident to anthracite coal mining; and that while, to men who daily see hundreds of tons of good culm thrown away, small savings of steam seem foolishness; yet in view of the great fact that in the best steam pumps in the coal regions the fuel used is four times as much as it might be, there seems room for improvement on that score. As the pumps now stand in the anthracite coal region, those which use the least fuel are the old plungers, worked by engines on the surface, using cog-wheels and pinions. Next in point of economy are the Bull pumps. Then follow various kinds of steam pumps—good, bad, and indifferent. None use the principle of expansion to a very great degree, and the duty done by 100 lbs. of coal may be stated at from 10,000,000 to 20,000,000 pounds of water raised one foot high.

The pumping of the water of the anthracite mines is an ever-increasing trouble. The mine widens, the out crops fall in, and as the quantity of coal to be had decreases, the water increases. For this state of affairs there is no help. Some collieries in the middle coal-field use, at certain seasons of the year, one hundred tons of coal per day for pumping water, to raise 8,000,000 of gallons in twenty-four hours, from a depth of four hundred feet. When wet seasons come on, the water in the mines gets more troublesome on account of acid which is extracted from the rubbish left in the mine. The water of the mines is not good for use for purposes of condensation, because, when heated to one hundred degrees, it acts on iron with increased force. Fresh water gets more and more scarce, and water is brought long distances by pipes, and often in cars, to supply the boilers; and in some districts good artesian wells are bored. Here, however, another trouble comes in: if the holes go down too deep, the mountain limestone is reached, and lime is more troublesome than sulphuric acid. But by mixing the two together, under intelligent care, a good water is obtained.

And so the situation is. The question that to-day troubles the minds of many engineers in the coal regions is, How had we best build our mine pumps—shall we stick to the old method of a plain steam pump, with no expansion or condensation, because it is so handy to put in and take out? So far as the pump alone is concerned, the answer seems, Yes; but when we see the long row of boilers, and immense piles of fuel for them, it calls attention to the other side of the question. If by this imperfect sketch, the writer shall have called the attention of this Society to this difficult and important question, he will be satisfied.

ON A NEWLY DISCOVERED VARIATION IN THE EFFECT OF PROLONGED STRESS ON IRON.

BY

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EARLY in the year 1874 the writer presented to the American Society of Civil Engineers a paper on "The Strength, etc., of Materials, as exhibited by a testing machine having an autographic registry," in which paper some singular and important effects of prolonged and intermitted stress were described for the first time. In considering the effect of time of application of stress, it was shown that a peculiar difference of effect was observable in metals accordingly as they belonged to the viscous or to the non-viscous classes, or, as the writer then stated it, to the iron or the tin class.

It was shown that soft metals are subject to a flow which causes gradual yielding under their maximum loads, while common iron and steel, on the contrary, exhibit a singular elevation of the normal limit of elasticity when subjected to intermitted stress. It was further remarked that the well-known experiment of Vicat *—in which he found that iron wire loaded with two-thirds its breaking weight, as determined by ordinary test, gradually yielded and finally broke, after two years under stress—were indications of the probability that this process of stiffening under load may, nevertheless, be accompanied by a flow causing ultimate fracture, if the load be heavy. No evidence of such flow had, however, been detected by the writer in ordinary iron, although occurring almost invariably with other metals.

It was finally concluded to repeat the experiment of Vicat in as nearly as possible the same way as the original tests were made.

Two samples of wire made by the Trenton Wire Works were furnished the writer by Mr. Wm. Hewitt, the Vice-President. Both were No. 36 wire (B. W. G.), 0.004 inch (0.1016 mm.) in diameter, and of the same kind of iron. One coil was hard-drawn, directly from the plates, and the other was very thoroughly annealed,

* *Annales de Chimie et de Physique*, 1834.

and, consequently, soft. Lengths of each kind of wire were carefully tested in the usual manner, to determine their strength under ordinary conditions of test, and similar lengths were then measured off for test by prolonged stress.

These latter specimens were suspended from a set of coiled springs hung from the ceiling in the study of the writer, where they would be constantly under his eye, and where, also, they would be safe against accidental injury. These springs were used because it was found that the jar due to the breaking of one wire was liable to injure those hanging near it.

After the wires were suspended they were carefully loaded, and were finally thoroughly painted with oil-paint, and left, carrying weights as below.

The table gives the weights in percentage of maximum loads under test, in the testing machine, in the usual way:

EFFECT OF PROLONGED STRESS—SWEDISH IRON WIRE.

Per Cent. Max. Static Load.	Time under Stress.	
	Hard Wire (Unannealed).	Soft (Annealed).
95	80 days	3 minutes.
90	35 "	5 "
85	18 months, still unbroken.	1 day.
80	3 "	9 months.
75		17 days.
70		15 months.
65	Unbroken.	" "
60		Unbroken.
55		"

These figures seem to reveal an important difference—previously undiscovered, so far as the writer is aware—between hard and annealed iron wire. Hard wire, unannealed and just as it left the draw-plate, sustained 85 per cent. its original breaking load, as determined by usual tests, eighteen months; and a wire loaded with 5 per cent. less weight, 3 months (the difference is probably due to some concealed defect in the latter), while the same wire, annealed and thus softened so much as to have carried about half as great a maximum load, broke under but 65 per cent. of that reduced load at the end of 15 months.

Those wires which are still unbroken will be left suspended, and, meantime, another series will be put under test. The final result will be reported to the Society in due time, should they all finally

break. The broken wires exhibit no traces of corrosion or injury, and the coat of paint with which they are covered is apparently as sound as when first applied.

These results evidently more than corroborate the experiments of Vicat, showing progressive disruption in both qualities of wire when heavily loaded. They also exhibit an unsuspected difference in the degree to which this occurs with hard and soft iron, showing the former to be, apparently, the safer. It is interesting to observe that the factor of safety for soft iron, under prolonged stress, must be as great as that for timber under the same conditions, both remaining uninjured by oxidation. These new facts have seemed to the writer so important that he has already announced the conclusion here given by publication in "Science." They are presented here also as being of especial importance to the engineer.

A NEW FORM OF BALANCE DYNAMOMETER.

BY

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THE Balance Dynamometer, represented by the accompanying drawings, was originally invented by Mr. Samuel Batchelder, then agent of the York Manufacturing Co., at Saco, Maine, in 1836.

The principle of the instrument is, that to hold a weight by the radius of a circle, in a horizontal position, at a constant distance from its center, takes as much power as to lift the same weight through the distance which would be traversed by it in any given number of revolutions around said centre or axis, and in the time required for such number of revolutions.

Thus, in the present instance, the scale-beam or steelyard is the radius of a circle, of which the circumference is ten feet, and the pin on which the weight is suspended would therefore traverse a distance of 1,000 feet in one hundred revolutions.

Now, one pound lifted 1,000 feet is equal to 1,000 pounds lifted one foot, and the weights used on the dynamometer are numbered accordingly.

Following out the operation of the machine, we will suppose that twelve pounds are held up on the scale-beam, and that the counter shows a speed of one hundred revolutions in six seconds, a worm and gear being arranged so as to ring a gong-bell at every one hundred revolutions of the shafts.

The twelve pounds, which are called 12,000 pounds, are then divided by the number of seconds consumed in the one hundred revolutions, and the result is $\frac{12000}{6} = 2{,}000$ pounds lifted one foot in a second, which result being divided again by 550, the equivalent expression for a horse power in feet per second, gives 3636 H.P. as the load passing through the machine.

The operation of the dynamometer is this: on the receiving shaft, in the present arrangement, are fixed a pair of fast and loose pulleys at one end, and a spur gear at the other. This spur gear drives a corresponding gear of the same size and number of teeth, which is fixed on the end of a sleeve or collar, having on its other end a bevel gear, which forms one side of what is known as a

"box" or "compound" gear. A corresponding gear on the opposite side of the "box" is fixed on the delivering shaft, which passes through the sleeve above mentioned, and also through the fulcrum of the scale-beam. The two remaining sides of the "box" are composed of a pair of equal and similar gears, which revolve freely around the scale-beam on either side of the fulcrum. One would really be sufficient for the purpose, but a pair is used in order to preserve a balance.

When motion is given to the shafts by means of a belt to the receiving pulley, the intermediate gears revolve about the scale-beam without effect; but when a belt is carried from the delivering pulley to the machine to be tested, the resistance causes the intermediates to act with the effect of levers on the scale-beam, and would put the latter in revolution about its axis or fulcrum, if it were not restrained by the weights, which are to be added and adjusted until a balance has been obtained.

It will be readily seen that the real motion of the scale-beam, were it free to move, would only be one-half that of the shafts, and the weights in actual use are therefore double their apparent value, or, in other words, the weight marked 1,000 pounds is in reality two pounds instead of one.

In the original machine as invented by Mr. Batchelder, only one shaft was used, on which a pair of pulleys was put on one end, and another pair on the sleeves, at the other, carrying the bevel. But this arrangement required a change either in the position of the machine to be weighed, or its driving pulleys, for every test, and a second shaft was added by Mr. Jas. B. Francis, of Lowell, in order to bring the receiving and delivering pulleys into the same driving plane, and a further addition was made by him, at the suggestion of the late Uriah E. Boyden, of the dash-pot, or hydraulic regulator. This is a cylinder filled with water or oil, in which a piston traversed with moderate freedom, and which is attached to the other end of the scale-beam in order to check vibrations and insure steadiness.

In the first machine built for Mr. Francis, and in several others either copied directly from it or slightly varied, the two shafts were upon the same horizontal plane, and increased the length of the floor space required, so that in many cases it was difficult to place the dynamometer in the ordinary alleys or floor space left between the machines in the cotton or woolen mills or machine shops.

This difficulty is obviated in the form of construction adopted

in the drawings by placing the shafts vertically, one above the other, and space is also economized farther by making the frame of iron, instead of wood.

The diameter of the dash-pot or hydraulic regulator is increased so as to obtain a more perfect resistance to vibratory or irregular motion, while the piston has sufficient clearance to move freely through the oil, which is used as a resisting fluid, at a slow velocity.

The bevel gears are of cast-steel. The central hub or fulcrum of the scale-beam, around which the intermediate gears revolve, and through which the shaft passes, is of phosphor-bronze, to ensure the necessary strength with the least friction.

A pair of pullies is provided for each shaft, the inner one of each pair being keyed fast to the shaft, while the outer ones are fitted with set screws, having proper seats sunk in the shafts, so that they can be locked, so as to make one wide driving pulley; or, by releasing the set screw, they can be made into a pair of fast and loose pullies, for the receiving shaft, according to the direction from which the belt is delivered, whether from above or below.

The gear teeth have been made of ample strength to resist the pressure of all the weights furnished with the instrument, if the whole strain were applied to one tooth, and as they are so cut that three teeth will always be in contact at the same time, the factor of safety is amply sufficient, and the power which can be weighed, by the use of all the weights, is equal to one horse-power for every hundred revolutions of the shafts, or to all the power which can be relied upon to be transmitted with safety by a single belt of 2½, or even 3 inches wide, although the pulleys are intended in the machine which we have built for a belt of 2½ inches.

The scale beams are made detachable for convenience in packing and transportation, and a "guide-wire," or "sight-rod," is added fitting into a socket in the frame, and standing, when level, parallel with the steelyard, by which the operator can easily see when he has attained his balance.

The floor space occupied by this instrument is 30x24 inches, and its weight for the machine alone is 284 pounds, the weights for use, which accompany it, being seventy pounds in addition. It will thus be seen that the Dynamometer as constructed gives the minimum of weight and space occupied for its capacity, and is easily adjusted in position and requires no change to be made in the position of the pulleys on the machine or shaft to be tested.

All that is necessary is to locate the Dynamometer in position to belt from the line shaft and on to the machine which is to be tested, to fasten the legs with four lag screws to the floor and to attach the belts—all of which is done in a short time. In every case the running balance of the Dynamometer when belted should be weighed before throwing off the belts after the completion of any test, and this balance weight deducted from the gross gives the net power consumed in the machine so tested. There has been exception taken by some engineers and others to the results obtained by Dynamometers, and in many instances there was good reason for so doing. Any form of Dynamometer depending on springs, actuated by centrifugal forces or otherwise, must in time become inaccurate, if not so when first constructed. The form described is thought to be the true one; and since it embodies the principle of a known weight actually lifted through a known space, it must be very accurate. As proof of this, it may be said that such a machine has been used for the past ten years, weighing over one hundred thousand H.P., in small amounts, and the totals, in some cases aggregating 250 H.P. have agreed within a few per cent. with the results obtained from indicator-cards taken from the engine driving the same machinery. In addition, numerous comparative tests, made with the Prony brake, all showed that the error, if any, was extremely small between the two, provided, of course, that the test were accurately made and with proper apparatus for a Prony brake. In these days, when economy of power is becoming such a study, a reliable instrument, easily applied, will be found an invaluable aid to engineers and others with whom the supplying or use of power is a source of profit.

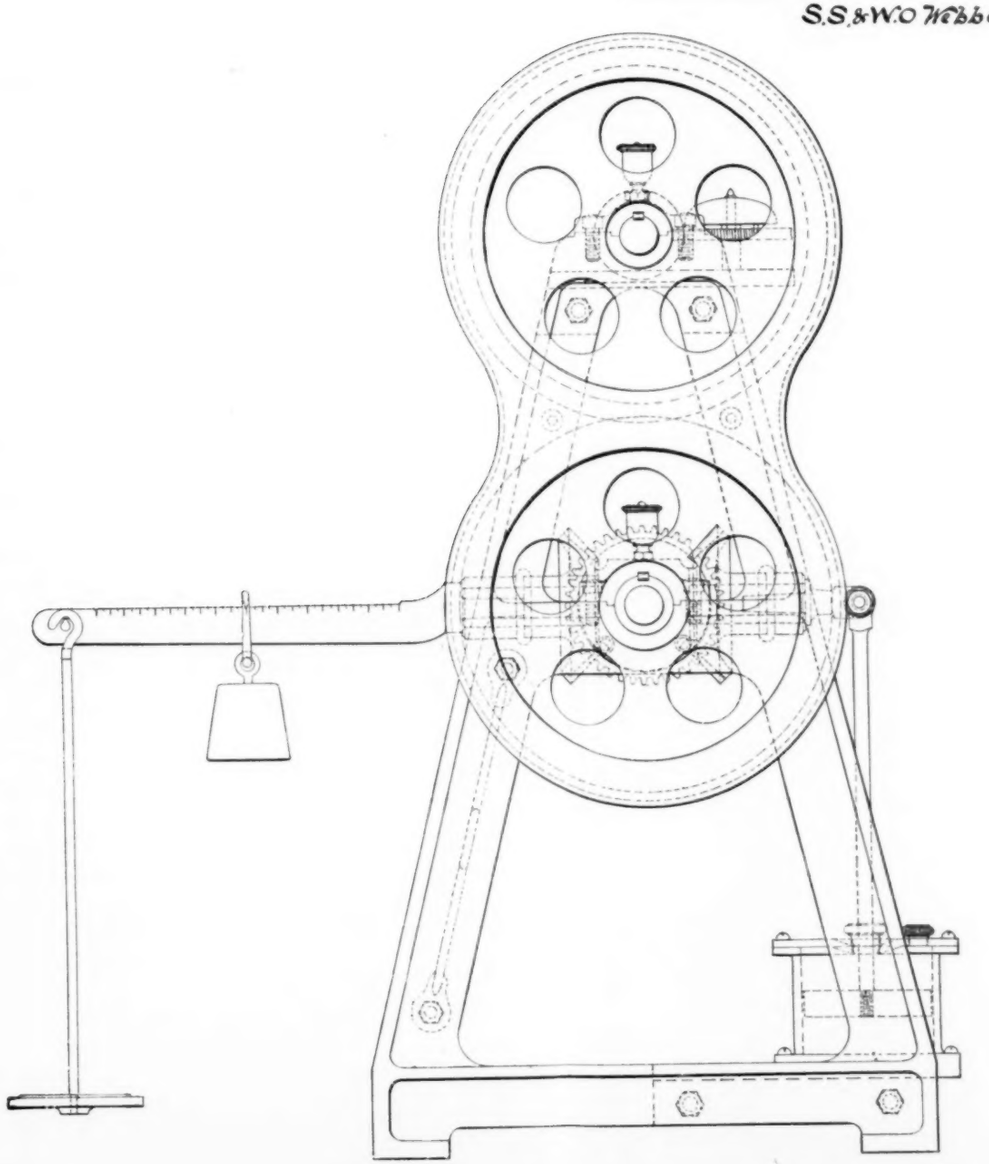
10 H.P. Balance Dynamometer.

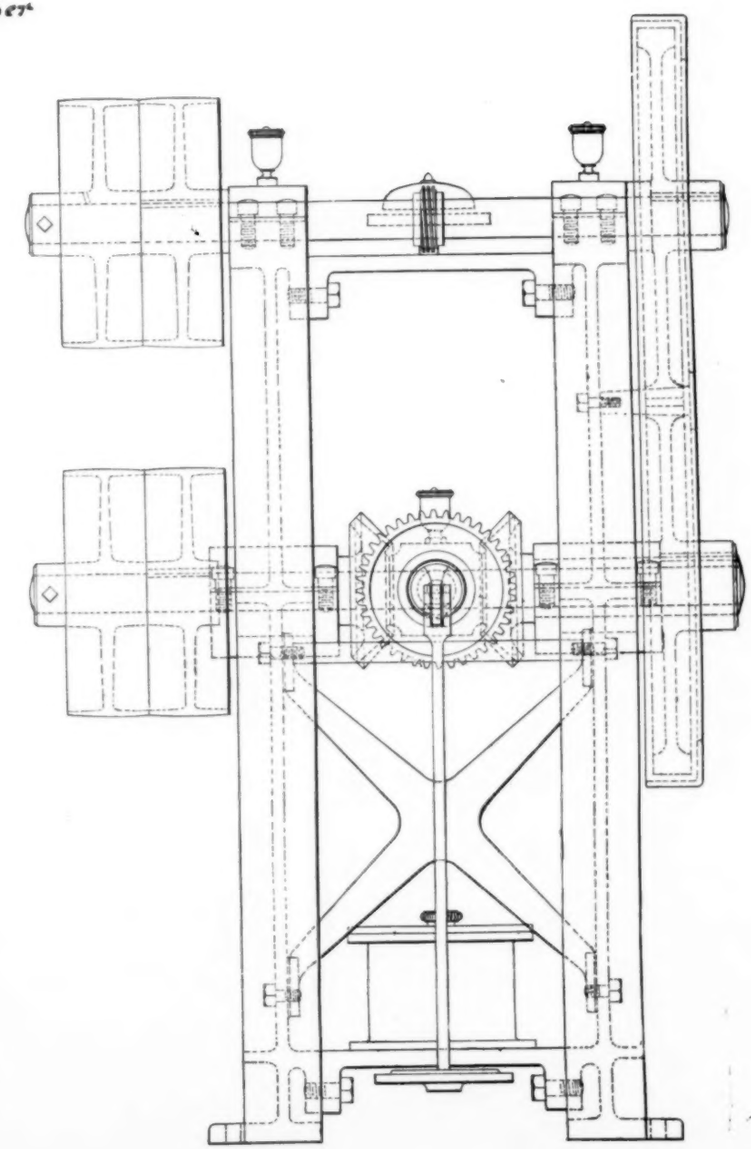
Built by

Lawrence Machine Shop

Lawrence Mass 1883

S.S. & W.O. Webber





A NEW METHOD OF CONSTRUCTING A CRANK SHAFT.

BY

JOHN E. SWEET, SYRACUSE, NEW YORK.

In making a pair of steel crank shafts larger than could be managed by the tools in the shop, if handled in the ordinary way, recourse was had to unusual means, and with so satisfactory results that it is hoped that a brief description will prove interesting and, to some extent, useful.

The crank disks, some 10 inches thick and 44 inches in diameter, had to have 10-inch holes for the shafts and 7-inch crank holes bored 15 inches between centres. To do this on a lathe in the usual way required a lathe of 6 feet 2 inches swing, and the unsatisfactory operation of moving and resetting each piece of a ton and a half's weight.

For use in ordinary work in the shop is a boring bar mounted on the carriage of the lathe, the axis of which is 9 inches below the centre of the lathe spindle. This boring bar is rotated by independent belt power, and the feed of the lathe is arranged to run independent of the lathe spindle, so that a piece fastened to the face plate of the lathe may have the holes bored in it when brought into the correct position. The trick was so to locate the disk on the face plate that both holes could be bored by simply rotating the face plate from one to the other. Fig. 1 shows the position when the shaft holes were bored, with the dotted lines showing position when boring the crank holes. The crank pin holes were bored 7 inches, and the pins, which were of tool steel, turned $7\frac{1}{1000}$ inches their entire length. Then the part that was to form the wearing surface was ground and polished to 7 inches, and the pins forced into the disks from the back, the finished portion serving as a guide to insure a fair start.

Next, so much of the rough shafts as was to fit the crank disks was turned and key-seated and the shafts forced in. For this an allowance was made of $\frac{1}{1000}$th of an inch, and is believed to be sufficient, since it required, as near as could be determined, about 90 tons pressure to force them in. To insure the shafts being truly parallel with

the crank, a cast-iron chuck, as shown at Fig. 2, was prepared to go over the out-board end of the shaft provided with four heavy set screws, and a 1½ inch reamed hole in the centre. In this hole was put a female centre, the rig forming an adjustable centre by which the out-board end of the shaft could be moved in either direction. With the shaft in the lathe, and one of Mr. Porter's V pieces and a sensitive level, it was possible to get the parallelism perfect. Removing the female centre from the chuck and putting in bushings to fit the centre drill and counter-sink, new centres were made in the shafts and the work finished eminently satisfactorily. So perfect had our method of boring the holes in the cranks proved that the final error did not exceed $\frac{1}{50}$th of an inch in the length of the 10-feet shafts.

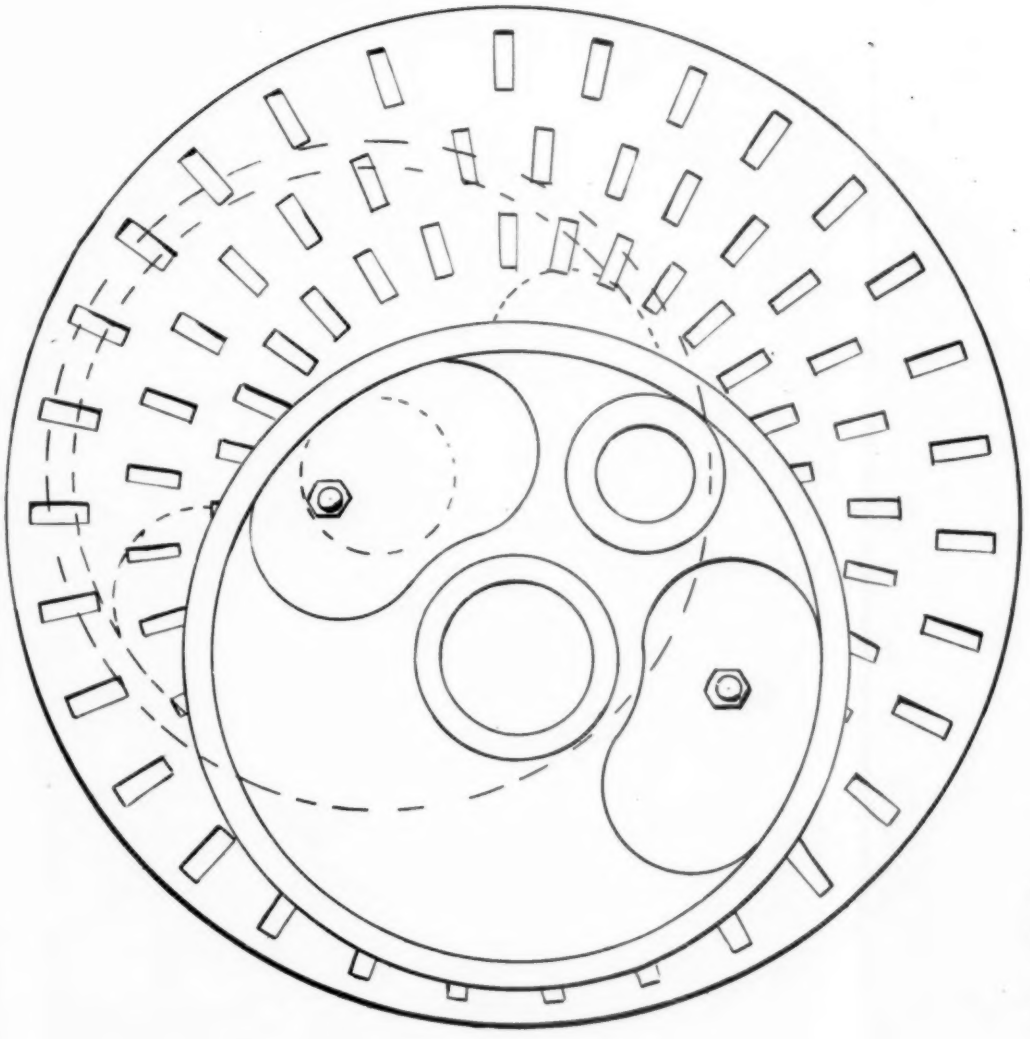


FIG. 1.

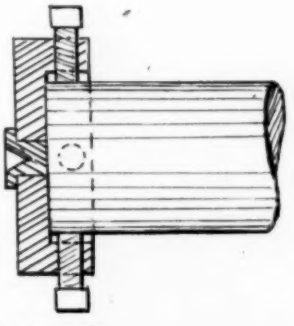


FIG. 2.

ECONOMY BY SUBDIVISION IN INSTALLATION AND OPERATION OF POWER AND MACHINERY UNDER VARYING DEMAND.

BY

JULIUS L. HORNIG, JERSEY CITY, N. J.

THE question of economy in the construction of steam engines or motors has been discussed with great ability and science, so that the importance of the subject is generally appreciated and a selection is made from the most approved constructions. The economy by suitable adaptation and installation is a question which requires the same attention.

This article is intended to treat, in general, of the propriety of subdivision in installation where varying service is required. Such cases arise in central stations for supply of power, water, light, etc., or in manufactories, where a number of tools or machines are consuming power at varying demand. The object of the writer is to lead to further discussion and elaboration.

The generators of steam, for power under varying demand, will show higher economy by suitable subdivision. The fact that the highest economy in steam generation takes place when the most perfect combustion takes place, indicates that the temperature of the fire should be kept nearest to this point. Therefore, a variation in the quantity of steam required demands that a variation in grate surface should take place, or, in other words, that more or fewer boilers should be operated accordingly.

The question of combination of smaller and larger boilers is worthy of investigation; and, also, the subject of loss of heat from boilers while the fire is banked, in comparison with the loss of heat from boilers at low temperature of fuel and losses consequent to that.

Steam engines, built for certain maximum capacity, will naturally show at full service the highest economy. Their loss by friction, inclusive of connections or transmissions to do work at a fixed speed, will be found essentially the same from minimum of work to their full capacity.

When work varies much, as, for instance, in the supply of light, this investigation proves important.

The attached economy-curves are worked out approximately from several systems of indicator-cards, and furnish the following:

Comparison Table of Useful Percentage up to Full Capacity.

Work-Divisions.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10th.
Per cent. for large Machine..	35	55	66	75	80	86	92	95	98	100
Per cent. for small Machine..	55	75	86	95	100					
Per cent. difference....	20	20	20	20	20					

The small machine, which has only half the capacity of the large one, doing the same work as the large machine, shows a gain of 20 per cent. if used instead of the large machine when the latter is worked only to half of its capacity.

To consider the loss, a few comparisons only may serve here. In assuming a number of the same class and size of machines installed, and referring to the curve of large machine, the per cent. of loss will be found:

Working 2 machines, $\frac{1}{2}$ capacity, in place of 1 full = 20.
" 3 " $\frac{2}{3}$ " " 2 " = 10.
" 4 " $\frac{3}{4}$ " " 3 " = 7.
" 5 " $\frac{4}{5}$ " " 4 " = 5.

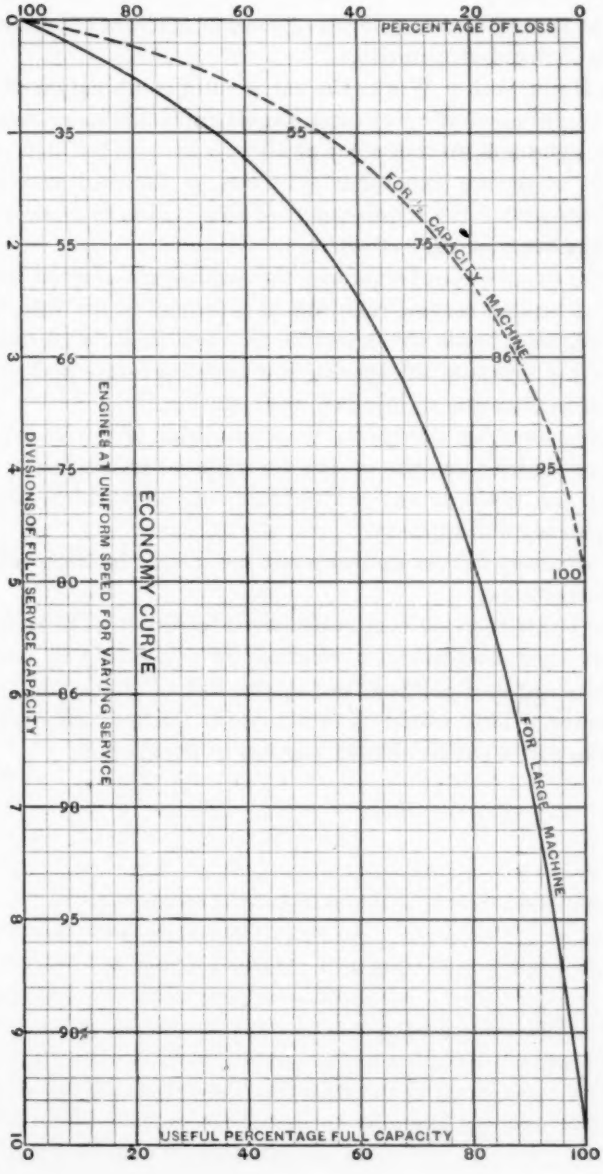
The curve shows a loss of:

20 per cent. for using a machine only $\frac{1}{2}$ capacity.
34 " " " " " $\frac{3}{10}$ "
54 " " " " " $\frac{3}{20}$ "

The combination of working machines of different capacity must be, evidently, advantageous, when using the smaller only for work up to its full capacity, then to change the work on to the larger up to its full capacity, laying the smaller up during the intermediate higher range, and add its service only at demand of rate above capacity of larger machine.

This combining of machines to keep their service nearest to their full capacity must secure the highest economy.

The rate of friction in steam engine and transmission in other installations will not vary much from electric light machinery taken here as sample, and therefore a similar importance must exist.


PERCENTAGE OF LOSS
100
80
60
40
20
0
35
55
66
75
80
86
90
95
98½
55
75
86
95
100
FOR ½ CAPACITY MACHINE
FOR LARGE MACHINE
ECONOMY CURVE
ENGINE AT UNIFORM SPEED FOR VARYING SERVICE
DIVISIONS OF FULL SERVICE CAPACITY
0
1
2
3
4
5
6
7
8
9
10
USEFUL PERCENTAGE FULL CAPACITY
0
20
40
60
80
100

This question of economy will apply to the installation of a number of pumps driven by a number of engines, where the service varies at times; also to a series of tools or machines operated under varying demand at factories.

The Holly Water Works Co. carry out a combination of several steam engines operating one main shaft and make steam connection to their cylinders, so that some or all may be used for high pressure, or some as second expansion cylinders, as demand may require. This should meet the requirement of subdivision in installation for economical service very effectively.

In first installations frequently the engines are adopted largely in excess of present service required, as a provision for future extensions, whereby losses are caused in the meantime by increased friction, by the necessity of carrying low steam pressure and by irregularity in motion due to injudicious expansion.

In transportation service the timely addition of the so-called hill-horse for vehicles and the pusher for railroad trains, at the steeper parts of the roads, is an established mode of working motors to nearest steady full capacity.

The auxiliary boilers and engines are found in large works for similar assistance.

From boiler tests on best constructed boilers it is to be assumed that the highest economy is reached by consuming $9\frac{1}{2}$ pounds of anthracite egg coal per hour per square foot of grate, producing 3, horsepower. This would give the ratio for best subdivision of boilers to suit a subdivision of engines in installation.

A NEW METHOD OF CASTING FLANGE PIPE.

BY

JOHN E. SWEET, SYRACUSE, NEW YORK.

EDISON says "he attributes a large part of his success as an inventor to the fact that he knows so many things that won't work"; and again, that "he does not think he can make many more mistakes, as he must have made them about all already."

Our experience in attempting to cast flange pipe so they should come out of the sand complete has often reminded me of Edison's remarks, for I now know lots of things that won't work, while the number of mistakes appears to have reached about 95 out of a possible hundred.

Having too much foundry an order was accepted for a lot of flange pipe, and having too small facilities for facing and drilling the attempt was made to cast the ends faced true and the bolt holes cored.

The plan consists in casting the ends of the pipe against a chill, and the arrangement is shown in the figures. Fig. 1 shows the pattern, which differs from the ordinary pipe pattern in having movable flanges to suit different lengths of pipe, and in having the core prints the full size of the flanges instead of the size of the bore.

The flask, Fig. 2, is of the ordinary iron sort, having ends adjustable at intervals of a couple of inches, and with openings in the ends equal to the size of the core prints.

The core bar, Fig. 3, is an inch or two smaller than the pipe, having circular flanges an inch and a half or two inches apart and four ribs throughout its entire length.

The core bar has the ribs turned true and to a given size, upon which is fitted two chills shown as AA.

The chills may be set in any position to suit the length of pipe required. The faces are recessed so as to form a facing for the packing on the finished pipe; and as many holes as there are to be bolt-holes in the flange are bored completely through the chill, accurately spaced and reamed slightly tapering.

The outsides of the chills are turned to the same size as the prints on the pattern, except that there is left on the outside a small sharp

projection about $\frac{1}{8}$ inch high—and this is the sharpest dodge in the whole scheme.

The chills when on the bar form journals, so that when rested in proper bearings the core bar may be rotated. Common moulding sand is used for the core, and when swept up is as true as if turned in a lathe. When the flask is rammed up and the pattern removed both ends are open to the full size of the flange. When the core is set the chills close up the ends except the holes for bolt cores, and the projecting V ribs are pressed into the sand and make a perfect stop to prevent the iron from running out.

Cores of the size of the bolt holes and some three or four inches in length are made and passed through the chills until they strike the green sand, so that when the pipes are cast the bolt holes are more nearly correct than the ordinary drilled holes.

For making the bolt hole cores we have blocks like the cylinder of a revolver, Fig. 4, with several holes in which the cores are made and baked, turning them out as perfect as if made by machinery. The faces of the pipe are smooth and good enough to pack with rubber gaskets.

This all seems simple enough now, but it worked with indifferent success until we learned the trade, and in learning the trade the apprentices made by far the best headway.

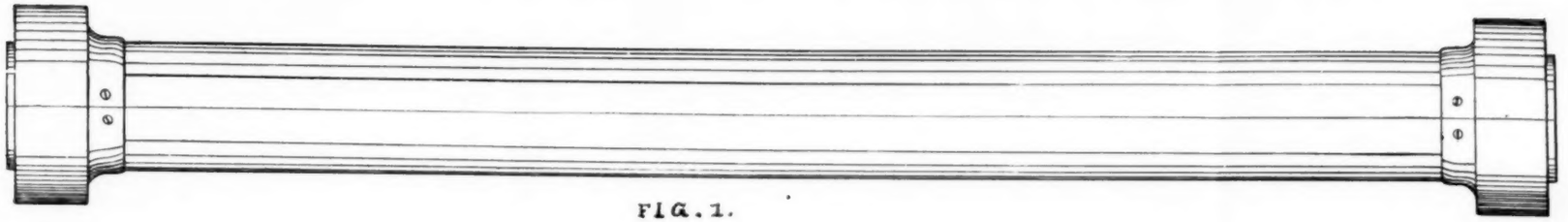


FIG. 1.

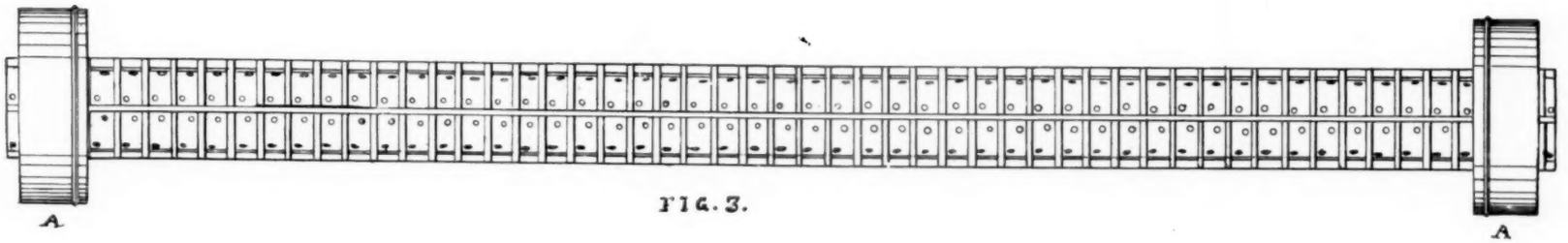
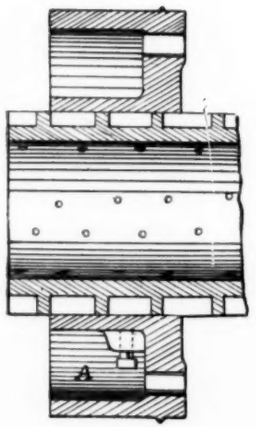


FIG. 3.



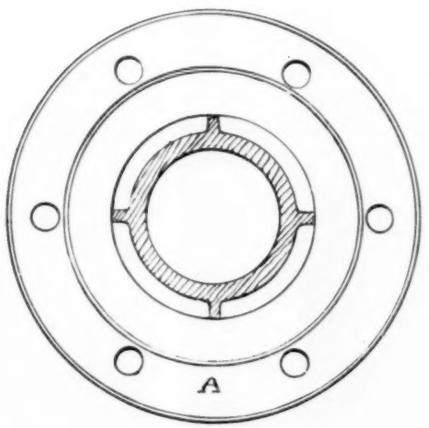


FIG. 4.

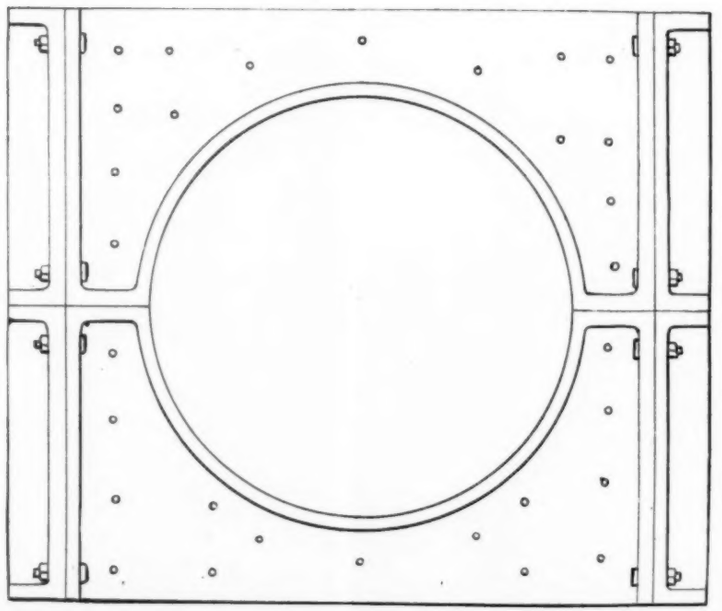


FIG. 2.

REMARKS UPON THE ORDINARY FORM OF BESSEMER INGOT CRANES.

BY

GRAM CURTIS, NEW YORK.

THE crane most generally met with in our Bessemer works is shown in Fig. 1. It is top-supported and has a hollow cylindrical mast of cast-iron, made in three pieces. The top and bottom pieces are carefully turned, each with a tapered end which fits a turned socket in the corresponding end of the middle piece. The top piece passes through a block in the roof, which forms the top support to the crane. The bottom piece is made the plunger of the hydraulic cylinder at the base, and the middle piece carries the wrought-iron jib and tie rods.

It is the purpose of this paper to follow the principal strains developed by a load upon such a crane, call attention to some weak points of the mast, and to suggest another, and in some respects a better, form of mast and cylinder.

Referring to Fig. 1, and also to Fig. 2, which shows merely the axis $a\ b$ of the mast with the forces acting upon it:

a is point of lateral support to mast at cylinder.

b is point of lateral support to mast at block in roof.

c and d are the projections upon the axis of mast of the pins in tie rods.

The weight of the jib with its load tends to revolve the mast towards itself, and for a given load this tendency is obviously greatest when the load is at the outer end of the jib.

Avoiding as far as possible, in the body of this paper, the mathematical formula, which will be found in the appendix, let us assume that a certain weight, W,—which includes the weight of the jib and ties, etc.,—placed at the outer end of the jib, is the greatest load that can be safely borne by the crane. W then creates the force P at c, and the force P' at d, and these forces in turn develop the resistances p' at a and p at b, and we may therefore neglect the jib and tie and consider the mast as a beam held at rest by the forces p, P', P, and p', and these forces by tending to distort the mast tax its strength.

In order to get the full use of the mast it ought to be taxed up to its safe limit, but at no place beyond it. In Fig. 2 the lines x-x, x'-x', x''-x'' are the lines of the safe elastic limit of the mast, constructed from formulæ which may be found in the appendix. That is, the length of the perpendicular distance from any point in the axis of the mast, $a\,b$, to this line, gives the measure of the resistance to bending which the mast will offer at that point, when the extreme tensile strain upon that cross-section of the mast is 5,000 lbs. per square inch—the limit to which it is deemed safe to expose cast-iron. We notice at the points t and t' where respectively the top and the bottom pieces are abruptly reduced from 13 inches diameter to 12 inches diameter, that the elastic resistance (see x') is considerably reduced. It is here 750,248 inch-lbs., therefore the distorting tendency of the forces p, P', etc., or the bending moment, as it is called, must not be at these points greater than the above amount. Now the weakest position of this mast is when it is at its extreme upper point of stroke. t' is then 123 inches from the force p', and hence p' multiplied by 123 inches must equal 750,248 inch-lbs., from which it follows that p' must be 6,100 lbs. By means of p' and formulæ given in appendix, we find that W is 6,521 lbs., and deducting for the weight of jib, tie-rods, etc., their weight reduced to end of jib, 1,891 lbs., we have left 4,630 lbs. as the extreme load which may be safely handled by this nominally 10-ton ingot-crane, with a total lifting power of 39,810 lbs., under 300 lbs. hydraulic pressure. From this total lifting power, deducting

Weight of mast (calculated) . . .	8,950 lbs.
" " jib, etc. " . . .	3,268 "
Friction at a and b ($33\% \times p$) . . .	4,066 "
" in stuffing box (say) . .	4,000 "
Making a total of	20,284 lbs,

we have left 19,526 lbs. with which to lift 4,630 lbs.; that is, the extreme load that can be safely handled is not quite 24% of the capacity of the crane.

These reductions in the diameter of the mast are certainly very unnecessary, and at the same time very serious errors in the design of the crane. Worse places for these reductions could not have been selected, and the error seems to have been copied into many,

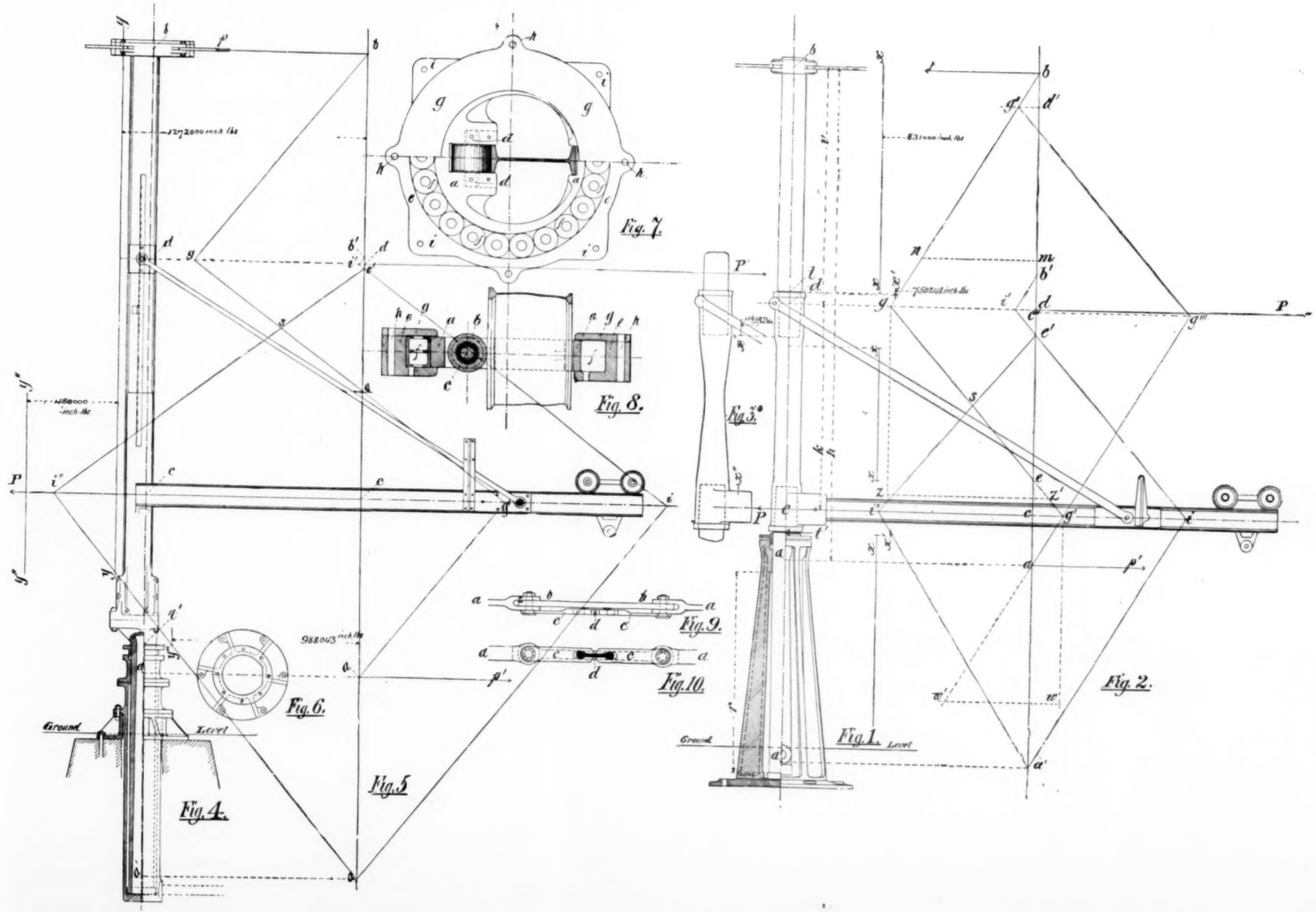


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

if not most, of the ingot cranes in use. The breaking of these cranes at one of the places referred to (generally at the upper point *t*) is not an unusual occurrence, and in view of this danger, the maximum load, in at least one of our Bessemer Works, has been limited to 3 tons (which is however more than the safe limit), and in all the Bessemer Works large loads on these cranes are handled very cautiously. By forming the top and the bottom pieces as shown in Fig. 3, merely carrying the full diameter 13 inches, all the way, and, as soon as the length of stroke will permit, slightly enlarging the mast before it enters the socket, the net load which may be handled with safety will be increased to 6,697 lbs.,—a gain of over 44 per cent.

Having obtained the value of *p*, we can by means of formulæ, given elsewhere, construct the lines of bending moments. This construction is shown in Fig. 2. When the crane is down *g b* is the line of moments for the upper part of mast *d b*, *g g'* is the line of moments for the middle part *d c*, and *g' a* is the line for the lower part *a c*. It will be noticed that the line *g g'* intersects the axis *a b* at *c*, locating a section of the mast at which there is no bending strain.

When the crane is in its highest position, *b g''* becomes the line of moments for the upper part, *g'' g'''* the line for the middle part, and *g''' a* the line for the bottom part. Transferring these lines to their proper position relative to Fig. 1, we see that the point of no flexure, or the neutral section of the mast, has traveled some distance up the mast during its stroke. We also find, as might have been expected, that the elastic strain sustained by any cross-section of the mast varies considerably during the stroke. Combining the two sets of moment lines we get *a'-i'''-s-g-b*, the diagram for determining the form of a mast of uniform strength safely to sustain the load *W* at the outer end of the jib. It gives the maximum bending moment to which each cross-section of the mast is subjected by this load at some one time during a full stroke. This may now be compared with the lines of elastic resistance *x—x*, *x'*, etc., and it can at once be seen at what points the mast is strong and at what points weak. The small moment at *s*, with the moments increasing above and below it, calls for a middle piece of the shape given in Fig. 3, and shows how unnecessary is the strengthening of this part of the mast by heavy ribs, as is sometimes done, especially in ladle cranes.

Before speaking of the modified form of mast for a crane of the

type we have been considering, I wish to call attention to the conflicting character, or, to say the least, the independent character, of some of the elements which are to be combined in determining the size of its various parts.

1st. *The length of the jib.* This, with the load, creates the bending strain on the mast, and with the 2d element, *the stroke of the crane*, it determines the diameter of the ram, thus fixing the lifting area to be acted upon by the 3d element, namely, *the hydraulic pressure.* Any two of these being given, the 3d practically becomes prescribed within certain limits, in order that the crane shall not be overtaxed or broken down by its own lifting power. If, however, they are all fixed, *we may, or we may not*, be able to construct a crane that shall be safe under the greatest load it can lift.

In the case we are about to consider all of these elements have been fixed; the first and second by convenience, and the third, probably, arbitrarily.

We will take the same sized ram as used in previous crane, and the same length (123 inches) of the unsupported cylindrical part at full stroke. The annular cross-section of this ram (13 inches outside and 7″ inside diameter) gives, at 5,000 lbs. per square inch tensile strain, an elastic moment of 988,043 inch-lbs., which divided by 123 (the unsupported length) gives 8,033 lbs. for the safe limit for the forces p' and p acting at a and b. This is the limit of strength of the ram and must not be exceeded; but by separating a and b, which may easily be done by sinking the cylinder into the ground, we increase the power of this limit for sustaining a load at the outer end of the jib.

Sinking the cylinder has several advantages: it increases its stability without widening its base, permits of a lighter shell, and allows the use of a smaller base-plate and lighter foundations. There are, however, some objections to it: the principal ones are placing the stuffing-box where it is more exposed to dirt, etc., and bringing the projecting parts of the mast closer to the working level. We have chosen 4 ft. above ground for the top of gland; this avoids, in a measure, the above objections, and permits the safe handling of a load of 8,918 lbs. net. By using a solid ram we may increase this net load nearly 1,000 lbs., and by making it hollow, with diameters as given above—but using steel instead of cast-iron—the safe load would be about 18,000 lbs., which might be still further increased by sinking the cylinder lower.

Having found p' (= 8,033 lbs.) we may, with the stroke and height of mast—given elsewhere—construct the diagram of bending moments—Fig. 5—and from it proportion our mast. A cast-iron mast of this size, of adequate strength, will be found cumbersome; a better mast may be made of wrought iron—a heavy 15″ I beam as shown. The line *yy* is the line of elastic moments as found from table of I Beams of the Union Iron Mills. We see that opposite the jib the strength of the I beam is not great enough. It is at a place, however, where it may easily be strengthened, and probably the cheapest way of doing so is by well-fitted cast-iron fish-plates as shown. The line $y''y''$ is the increase of the elastic moment due to these plates, which clasp the lower end of the beam, and by very heavy flanges at the bottom receive the ram. Projections from these castings are carefully fitted into notches in the flanges of the beam. The ram immediately upon leaving the gland of the cylinder is enlarged to meet the casting just described. The cylinder is made with a flange—or with 8 separate ribbed lugs if desired—around its body, about 15 inches from its top end. The form of base-plate (see, also, Fig. 6) is light, and admits of through bolts for securing the cylinder.

The *top-support* for this form of mast is shown in Figures 7 and 8. It consists of a cast-iron ring *a*, which carries a wheel *b*, running on friction rollers. The steel shaft *c* is about 2½″ diameter, and is flattened bottom and top for a few inches on each end, so as to set into sockets at *d*, *d* in ring *a* and be held without revolving. The frame *e* has a lower ledge or flange to support the ring *a* and the light cast-iron rollers *f*, *f*. The cover *g* secured by bolts through the holes *hh* is placed over the ring *a* and rollers *f*, *f*. The lugs *i*, *i* receive the guy-rods. With care in casting the different parts, this top-support can be fitted up with very little machine-work. The rollers *f*, *f* are free, as are also the rollers in the wheel *b*. The former being short in proportion to their diameter, have no tendency to fall on their sides.

The calculated weights of masts and cylinders of these cranes are as follows:

Crane—Figure 1.

Mast	8,950 lbs.	
Cylinder	7,220 "	
Base-Plate	3,981 "	
		20,151 lbs.

Crane—Figure 4.

Mast	Cast-iron.....	5,809 lbs.	
	Wrought iron.	1,970 "	
Cylinder.....		4,187 "	
Base-Plate.....		2,097 "	
			14,063 lbs.

Difference in favor of Crane, Fig. 4: 6,088 lbs.

The mast and cylinder of crane, Fig. 4, compare favorably with those of Fig. 1 as regards cost of construction; the top support, however, is more complex. Its lifting power, like the crane of Fig. 1, however, is far beyond its safe load, as is shown by the following:

13″ dia. = 132.7″ area × 300 lbs. pressure = ...			39,810 lbs.
Weight of mast		7,779 lbs.	
" jib, etc.....		3,268 "	
Friction, 33 per cent. of p.....		2,678 "	
" at b, assume.....		500 "	
" in stuffing box, assume		4,000 "	
			18,225 "
Leaving a net lifting load of.....			21,585 lbs.

with which to lift 8,918 lbs., or the safe load is little over 41 % of the power of the crane. It would seem that there is room here for the introduction of a "breaking block," or a piece the breaking of which without injury or derangement to the crane, would give warning that the load was exceeding the safe limit.

In Figs. 9 and 10 is shown an arrangement designed for this purpose; one is introduced into each tie rod. The tie rod $a\ a$ is forked, and there is inserted a link of tough, fibrous iron, having its cross-section of such a size that the bar will commence to stretch under the maximum load: $b\ b$ represents this bar, and $c\ c$ are castings carrying a small tell-tale bar d (shown in solid black) of brittle cast-iron, with a very small cross-section. Any stretch of b will cause the breaking of d, and this, together with the hanging down of the castings $c\ c$, reveals the fact that the safe limit of the crane has been reached. The tell-tale bar d goes into place from the back, when the link $b\ b$ is inserted, and a small lug or flange, which the bar carries, prevents it from working through. It therefore

remains loose until bound or broken by the stretch of the link, and as soon as this occurs the ends of the castings drop as described. Every time the crane is strained beyond its safe limit, new links $b\ b$ and new bars d must be inserted.

Having noticed such serious defects in the ordinary form of ingot-crane, it may not be out of place, in conclusion, to mention a form of crane in which these defects may be avoided, namely, the Wellman, or rolling jib crane. This crane is admirably adapted for safety and strength, and also for economy of water. The two wrought-iron beams which form the mast may be proportioned to resist the bending strain from any desired maximum load, and the cylinder (placed between them) proportioned so that a greater load cannot be lifted. The improved form of these cranes has two concentric rams, and by using the inner or smaller ram for light loads an economy of water is effected.

For economy, however, the hydraulic crane is not conspicuous. As much work is expended in lifting an empty crane as is required to raise the same when loaded to its full lifting capacity: this follows from the fact that the same number of cubic inches from the accumulator are required in each case. With the empty crane, the surplus work is expended in friction in pipes, valves, etc.

Appendix.

Referring to Figures 1, 2, 4, and 5,

a = point of lateral support to mast at cylinder.

b = " " " " at block in roof.

c & d = projections on the axis of the mast of the pins in the tie rods.

h = distance from a to b = 263″ (in Figs. 1 & 2) = 331″ (in Figs. 4 & 5).

k = distance from c to d = 110″ (in Figs. 1 & 2) = 125″ (in Figs. 4 & 5).

v = variable dist. b to d = 126″ to 18″ (in Figs. 1 & 2) = 112″ to 4″ (in Figs. 4 & 5).

l = working length of jib = 246″ (in Figs. 1 & 2) = 246″ (in Figs. 4 & 5).

r = stroke of crane = 108″ (in Figs. 1 & 2) = 108″ (in Figs. 4 & 5).

W = greatest weight, including ties, jib, etc., etc., reduced, that can be safely borne by the crane at the outer end of the jib.

Formula for elastic resistance of annular cross-sections is

$$M = .0982 \times \frac{D^4 - d^4}{D} \times f.$$

In which D = outside diameter
d = inside "
f = limit of strain for material—in this case 5,000 lbs. tensile strain per square inch.

By substituting in this equation the values of D and d given in the following table, we obtain the moment by which the lines $x\,x$, x' etc., are laid off:

	D	d	Moment (M)
From b to t	13″	9″	831,000 inch-lbs.
At t	12″	7″	750,248 "
Middle piece	16″	11″	1,561,840 "
" "	13″	9″	831,000 "
At t'	12″	7″	750,248 "
Ram	13″	9″	831,000 "

From which we see that at t and t' are the weakest moments in the mast. W should then produce at one or at both of these sections a bending moment = 750,248 inch-pounds. W causes the moment Wl, which reaches the mast at c and d as the forces P' and P, forming the moment Pk, which in turn develops the resistances p' and p at a and b, giving rise to the moment ph. Hence:

$$Wl = Pk = ph \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The force p must then cause at t, or the force p' must cause at t', the moment 750,248 inch-pounds. The distance $t\,b$ varies with the stroke of the crane from 120″ to 12″, and simultaneously the distance $t'a$ varies from 15″ to 123″, hence p multiplied by 123″ must equal 750,248 inch-pounds, or p = 6,100 lbs, and from equation (1) we find P = 14,585 lbs., and W = 6,521 lbs. Hence the safe load is 6,521 − 1,891 = 4,630 lbs.; 1,891 lbs. being the weight of jib, ties, etc., reduced to the end of the jib.

The forces p, P', P, and p' form bending moments and develop in the mast equal resisting or elastic moments M.

Let x be the distance of any cross section of the mast from the point b, and let this distance increase from $x = 0$, to $x = h$. For bending moments in the mast we then have:

For the part $b\,d$, or from $x = 0$ to $x = v$,

$$px = M \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

For the part $d\,c$, or $x = v$ to $x\,v + k$, $px - P\,(x - v) = M$, or $pv + p\,(x - v) - P\,(x - v) = M$; or factoring

$$pv - (P - p)\,(x - v) = M \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

For the part $c\,a$, or $x = v + k$ to $x = h$, $px - P(x - v) + P[x - (v + k)] = M$, or $p(v + k) + p[x - (v + k)] - Pk - P[x - (v + k)] + P[x - (v + k)] = M$, reducing $pv + pk + px - pv - pk - Pk = M$, and factoring

$$pv - (P - p)k + p[x - (v + k)] M = \ldots \quad (4)$$

If we make 1″ in the drawing to equal 100 lbs., then in Fig. 2, the line bp, 61 inches long and perpendicular to ab, the axis of the mast, represents the force p; and similarly the horizontal lines P'' P, and p' represent those respective forces. To construct equations (2), (3), and (4) we assume 100″ for the unit measuring the distance from any force to any cross section, lay off $x = bm = 100''$, and make $mn = p = 61''$; the line bn, continued to g, its intersection with the direction of P' is then the graphical construction of $px = M$, equation (2), or the line of moments for the part of the mast bd. In a similar manner, pv, being represented by the line gd, making gz (parallel to ab) $= x - v = 100''$, and the perpendicular $zz' = (P - p) = 84.85''$ the line gz' extended to g is the moment line for part cd. And in like manner (the line eg' representing $pv - (P - p)k$) making $g'w = [x - (v + k)] = 100''$, and $ww' = p$, the distance $g'a$ on the line $g'w'$ will be the moment line for the part ca. When the crane is at its extreme upper point of stroke e becomes e' and d becomes d', and hence bg'' becomes the moment line for bd', $g''g'''$ for $e'd'$ and $g'''a$ for $e'a$. Transferring this last set of moment lines to $a'i$ $i'b'$, its position relative to Fig. 1, and combining, we get a' i'' s g b, the diagram for mast of uniform strength. Diagram Fig. 5 is constructed in like manner, the same letters referring to like parts.

At t', Fig. 4, is the cross section limiting the strength of the ram to resist flexure; here $D = 13''$, and $d = 7''$, whence the limit of elastic movement M, is 988,043 inch-pounds. The distance $t'a = 123''$, and therefore putting $123'' + p = 988{,}043$ inch-pounds, we find $p = 8{,}033$ lbs., and by equation (1), $P = 21{,}271$ lbs., and $W = 10{,}809$ lbs.

The elastic moment of a heavy 15″ I-beam, deduced from the Union Iron Mills tables (safe uniform load for 1 foot span = 424′ tons) is

$$\frac{424 \times 2{,}000 \times 12}{8} = 1{,}272{,}000 \text{ inch-pounds.}$$

Assuming each splice plate to have a cross section at least 12′

high by 2″ broad, we have by substituting in the formula for elastic resistance of rectangular cross-sections, viz.:

$M = \frac{1}{6} bh^2 \times f$, 480,000 inch-pounds elastic resistance due to the plates.

For a solid ram, $d = 0$, we have $M = .0982 \times D^3 \times f = 1{,}078{,}727$ inch-pounds, whence $p = 8{,}770$ lbs., and $W = 11{,}800$ lbs., and net load $11{,}800 - 1{,}891 = 9{,}909$ lbs.

THE EVAPORATIVE POWER OF BITUMINOUS COALS.

BY

WILLIAM KENT, M. E., NEW YORK.

THE report made to the Navy Department in 1844 by Prof. Walter R. Johnson, of "Experiments on the Evaporative Power and Other Properties of American Coals," has long been accepted as a standard work of reference, not so much on account of the real value of the information it contains, as on account of the fact that, during the nearly forty years that have elapsed since its publication, no work on the subject of which it treats has appeared to supplant it. In many respects it is an admirable report, giving a faithful record of carefully conducted experiments, and including the proximate chemical analysis as well as the apparent evaporative power of the coals tested. It has, however, two very serious defects—it does not treat at all of any American coals mined west of Pittsburgh, and it does not give the real evaporative powers of such of the bituminous coals as were tested, but only their apparent evaporative powers as shown under conditions unfavorable to the development of the best results.

A pamphlet has recently been published by the Quartermaster-General of the U. S. Army, Gen. M. C. Meigs, entitled "Report on Fuel for the Army," which contains the results of 106 experiments with various coals, 75 with a vertical water-tube boiler known as the Little Giant, rated at five-horse-power, and 31 with a vertical water-tube boiler of about the same capacity, designed by Gen. Meigs. Of the experiments with the Little Giant boiler, 25 were made with Pennsylvania anthracites and 50 with semi-bituminous, bituminous, lignite, and cannel coals; with the other boiler six experiments were made with Pennsylvania anthracites, and 25 with semi-bituminous, bituminous, lignite, and cannel coals. A very much larger number of coals were tested than in Johnson's experiments, and the series included coals from nearly every section of the United States and also some foreign coals. In the letter transmitting the report to the Secretary of War, Gen. Meigs states that the object of the experiments was a careful determination of the *actual value, as fuel*, of the various kinds of fuel purchased and issued for the use of the army.

These numerous experiments having been conducted at Government expense, with all the facilities which the War Department is capable of affording, by Mr. L. M. Zuncker, "a mechanical engineer, educated at the Polytechnic School, Carlsruhe, Germany," in the light of the American experiments of forty years ago, and of various experiments in foreign countries in more recent times, it might be expected that this report would be an exceedingly valuable one, and that we would find in it either the actual value, as fuel, of the various coals of the United States, or, at least, their relative values as fuel for producing steam. As a matter of fact, however, the report is a disappointing one, and not at all valuable nor creditable to the department which issued it. It contains no analysis of the coals, nor any measure of their heating power. The various coals are used by the army as fuel probably more for heating purposes than for raising steam, yet the report assumes that the heating power of a coal is the same, relatively, as its power of raising steam "in a good steam boiler." If the report did contain even accurate determinations of the steaming power of the various coals without any attempt at determining their heating power when burned in a heating furnace, or stove, or grate, it would still be valuable, and would take the place of Johnson's report; but, instead, it has all the errors of Johnson in determining the relative steaming values of the bituminous coals intensified. All that the report does contain is simply a statement of what evaporative results were obtained from small quantities (145 to 1,200 lbs.) of various coals burned at approximately uniform rates of combustion, in a pair of boilers which were entirely unsuitable to the development of even the correct relative steaming power of nearly all of the bituminous coals, especially those mined west of the Alleghany mountains, and containing 30 per cent. or more of volatile matter.

Gen. Meigs himself recognizes that the results he obtained are inferior to Johnson's. "In order," he says, "to bring its [the Little Giant boiler's] inferior results to the same scale as Johnson's, which are assumed as exact, it has been necessary to use a co-efficient by which the results of the trials by the Little Giant boiler are corrected, in order to make them comparable with Johnson's." He says further: "The boiler used in Johnson's experiments on the evaporative power of coal was expressly constructed for that purpose. It was more economical, more efficient. The co-efficient to make the Quartermaster-General's office results comparable with Johnson's is 0.843, and dividing the Quartermaster-

General's office results by this fraction we have figures comparable with Johnson's."

The report does not state how this co-efficient was arrived at. It may have been obtained by averaging results, and is approximately correct for anthracite coals, and for the free-burning, semi-bituminous coals of Maryland; but for Pittsburgh coals, the results obtained with the Little Giant boiler, even after dividing by the co-efficient, are more than 10 per cent lower than Johnson's, with Newcastle (English) coal 30 per cent lower, and with Scotch coal, which happens to be the lowest in Johnson's whole list, over 11 per cent lower.

The results obtained by Gen. Meigs may be thus briefly summarized: With the Little Giant boiler, with 25 anthracite coals, the number of pounds of water evaporated from and at 212° per pound of coal varied from 8.68 down to 7.59 pounds, and after being divided by the co-efficient 0.843 from 10.29 down to 9.00 pounds. With the same boiler, with 49 bituminous coals, after being divided by the co-efficient, only two—a Somerset County, Pa., and a Cumberland, Maryland, coal—showed an evaporation of over 9 pounds, viz., 10 and 9.96 pounds. The third, a Colorado; fourth, a West Virginia; and fifth, a Colorado, showed respectively 8.59, 8.34, and 8.04 pounds. The sixth, a Pittsburgh coal, shows 7.84. The next five coals—two Pittsburgh, one Indiana, one New South Wales, one Indian Territory, and one Vancouver's Island—show over 7 pounds. Then come eighteen coals, including one from Pittsburgh, two from near Youngstown, Ohio, two Scotch, and one English coal, between 6 and 7 pounds; ten coals between 5 and 6 pounds, eight between 4 and 5 pounds, and one, a Utah coal, only 3.79 pounds. Thus 47 out of 49 bituminous coals, taken from nearly all parts of the world, give poorer results than the poorest obtained from the Pennsylvania anthracites.

With the boiler designed by Gen. Meigs, there were only 6 anthracites and 25 bituminous coals tested. It happens that two of the semi-bituminous coals, both from Somerset county, Penn., give better results, viz., 9.85 and 9.75, than any of the anthracites; then follow four out of the six anthracites, from 9.37 to 9.07; then one of the Pittsburgh coals appears, 9.07; then the other two anthracites, 9.04 and 8.87; and then the second Pittsburgh coal, 8.78. The two Pittsburgh coals which gave in these tests 8.78 and 9.07, showed in the Little Giant boiler test, even after dividing the results by the co-efficient, only 6.74 and 7.84 respectively the differ-

ences being respectively more than 23 and more than 13 per cent. This fact alone is sufficient to show the total unreliability of these tests. A Scotch, and an English coal also, which in the Little Giant boiler, after dividing by the co-efficient, gave only 6.25 and 6.07 pounds, in Gen. Meigs' boiler gave 7.61 and 7.52 pounds. The lowest coal on the list is a Dakota lignite, which gave 4.03 pounds evaporation; it gave 4.47 in the Little Giant test, after dividing by the co-efficient, and is the only coal in which an important difference in its favor appears in the latter test. Of the 25 bituminous coals tested in Gen. Meigs' boiler, 22 show results below the lowest of the six anthracites.

With both boilers, the tendency of the figures is to place the bituminous coals in general far beneath the anthracites in evaporative power. In this I think the tests are utterly misleading, and worse than worthless.

I have prepared a table (Table I. in the Appendix), which gives a selection of figures from various experiments on bituminous coals, including those of Gen. Meigs, arranged as nearly as possible in geographical order. The table also contains the percentage of refuse obtained in the trial, and the percentage of volatile matter, as determined by analysis, whenever these are given by the authorities consulted. Table II. gives the analyses of the coals whose analyses are reported.

The first portion of the table, headed "Continent of Europe," gives some of the results of the tests of Scheerer-Kestner and C. Meunier-Dollfus, reported to the Société Industrielle de Mulhouse. The first six coals whose percentage of volatile matter are given are nearly similar in composition to the Pittsburgh coals, except that they have a much greater percentage of ash. As these same coals were not tested by any other of the authorities here noticed, the results are scarcely comparable with those of American coals; but one point is worthy of notice: The Ronchamp coal, although containing a very high percentage of ash, gives the highest evaporation, and it contains much less volatile matter than the other five coals, while the Louisenthal coal, containing less ash than the Ronchamp, but the highest percentage of volatile matter, gives the lowest evaporation. This corresponds with the results both of Gen. Meigs and Prof. Johnson, in showing that the higher the percentage of volatile matter, the lower is the evaporative power (as shown by their boilers—not as might be shown under better conditions).

In the English coals, which are all highly bituminous, we notice that the two results of Johnson agree very fairly with the average results of Delabeche and Playfair; that in Johnson's results the highest evaporation corresponds with the lowest percentage of volatile matter; that in Delabeche's and Playfair's results the highest evaporation corresponds with the lowest percentage of *oxygen* and nitrogen, and *vice versa*, notwithstanding the fact that the lowest evaporation corresponds with the *lowest* amount of ash. We also observe that the results with Gen. Meigs' boiler are lower than either Johnson's or Delabeche and Playfair's, and that the results of the Little Giant boiler are the lowest of all.

In the Welsh coals, in Delabeche and Playfair's results, we notice that while the percentage of ash is higher than in the Newcastle coals, the evaporation is higher, and here also we trace the effect of lower oxygen, nitrogen and hydrogen, in increasing evaporative power (in their experiments). The tests by the Babcock and Wilcox boilers, both in London and in San Francisco, give results very much higher than Delabeche and Playfair's, the probable cause of which will be noticed hereafter.

In the Scotch coals, we are fortunate in having both Johnson's and Delabeche and Playfair's analyses, and the results of tests by five different authorities. Delabeche and Playfair's analyses show them to be very nearly the same as the Lancashire coals, and their evaporative tests of the two coals show nearly the same results. They show also that although the Scotch coal has a little less ash than the Welsh, its evaporative power is very much less, and this we connect with its higher percentage of oxygen, nitrogen and hydrogen.

The English and the Scotch coals appear very nearly alike in both Gen. Meigs' and the Little Giant boiler tests; but in both, and especially in the latter, both coals give very much poorer results than in any other boiler. For some unexplained reason, the Scotch coal figures the lowest in the whole list of Johnson, and more than twenty per cent. lower than Newcastle coal.

Since we have Delabeche and Playfair's analyses of Scotch and Welsh coals to compare with their evaporative tests, we may ascertain whether the difference in analysis is sufficient to account for the difference in evaporative results. From the formula, Heating Power $= 14500 \left\{ C + 4.28 \left(H - \frac{O}{8} \right) \right\}$ we obtain the theoretical heating power of the Welsh coal, 14,816 heat units, equivalent to

an evaporation of 15.35 lbs. of water from and at 212, and for the Scotch coal 14,136 heat units, equivalent to an evaporation of 14.65 lbs. As the actual results obtained were respectively 9.05 and 7.70 lbs., they show that Delabeche and Playfair obtained in actual test 59 per cent. of the theoretical heating power of the Welsh coal, and only 52.5 per cent. of the heating power of the Scotch coal—an economic result in favor of the Welsh coal of 12.4 per cent. $\left(\frac{59 - 52.5}{52.5}\right)$ Johnson obtained 47.4 per cent. of the theoretical heating power of the Scotch coal, the Meigs boiler 51.9 per cent., the Little Giant boiler (results divided by 0.843) 42.2 per cent., and the Babcock and Wilcox boiler 78.6 per cent., provided of course that the particular coals used in each of these tests had the same theoretical heating power.

But little can be said of the Nova Scotia coals, as we have only Johnson's two tests for comparison. The Pictou and Sidney coals seem an exception to the rule, already noticed, that the higher evaporative power corresponds under usual conditions with lower percentage of volatile matter as well as lower percentage of ash.

Coming to the Pennsylvania coals, we notice a group tested by Johnson, Nos. 30 to 35 inclusive, which are properly classed as semi-bituminous, having from 13.82 to 20.52 per cent. of volatile matter. They are especially noticeable from the fact that notwithstanding their rather high percentages of ash, they show the highest evaporative powers on Johnson's whole list. The two coals of Somerset County, Nos. 37 and 38, tested by Gen. Meigs, are coals of similar character, and they give the highest results of any bituminous coals tested by him, and, in the tests with the Meigs boiler, higher results even than any of the six anthracites. The high steaming quality of these coals is confirmed by the Babcock and Wilcox test of Cambria coal No. 44, containing only 13.24 per cent. of volatile matter. Notwithstanding the very high percentage, 25.1, of ash, the test showed an evaporation of 9.59 pounds of water per pound of coal, and 12.80 per pound of combustible, which latter figure exceeds the figures obtained in the tests of Scotch and of Welsh coal.

For a fair comparison with these coals we may turn to the Maryland coals, where Isherwood's, Johnson's and Little Giant tests all give high figures, and which are remarkably close ones, 9.69, 9.99, and 9.96. The Cumberland coal ranks second highest of the 50 bituminous coals tested in the Little Giant boiler, and also the

highest in Johnson's tests. It would appear that these coals, containing from 13 to 20 per cent. of volatile matter, notwithstanding occasionally high percentages of ash, prove good steaming coals under a variety of conditions and in a variety of boilers. They seem especially adapted to marine, vertical tubular and other internally fired boilers, which have heating surfaces all around the fire, and no special appliances for promoting perfect combustion.

With No. 36, in the Pennsylvania coals, we strike a very different quality of coals from the above. The Pittsburgh, or Monongahela River coals, are the type of this class. They generally have small percentages of ash, and high percentages of volatile matter (30 to 40 per cent.), approaching in composition the English, Scotch and Welsh coals, although not often found as pure as these latter. With these coals we reach the real difficulties of burning bituminous coals, and in consequence the results obtained under varying conditions, and with various boilers, differ widely. We notice that Pittsburgh coal No. 40 gave an evaporation of only 6.74 pounds in the Little Giant boiler, and 8.78 in the boiler of Gen. Meigs. Johnson found 8.20 for a Pittsburgh coal, while the Babcock and Wilcox tests gave from 8.12 for fine slack to 10.47 for lump (No. 46.)

Still more discordant results than these have been obtained from the same identical lot of Pittsburgh coal when burned under different boilers in different furnaces. At the Cincinnati Exposition of 1879, Mr. John W. Hill made five tests, in as many different furnaces, of Pittsburgh coal No. 2, all of the furnaces having been designed for "smoke consumers." The evaporation per pound of coal from temperature of feed varied from 5.839 to 9.688 pounds, but according to Mr. Hill's corrections for "heat in the steam," it varied from 4.828 to 12.450 pounds.

The Virginia coals tested by Johnson contain on an average less volatile matter than the Pittsburgh coals, and follow the general rule of showing a correspondingly higher evaporation.

The bituminous coals west of Pittsburgh were not tested by Johnson, and the tests by Gen. Meigs do not show the analyses, so that we have scarcely enough data for comparison. We notice, however, the very low figures, 6.82 pounds and under, for the coals of Tennessee, Ohio and Nebraska, all of which contain less than 7 per cent of refuse. The high results obtained by the Babcock and Wilcox boilers from Illinois "run of mine" coal (name of mine not known) and Indiana block coal, 9.49 and 9.47 respectively, are no-

ticeable, but as we have not the analyses no accurate conclusion can be drawn from them.

We come now to a very peculiar coal from Staunton, Ill., tested under a Babcock and Wilcox boiler at Springfield, O., which gives the figure 5.09—remarkably low as compared with all the other Babcock and Wilcox tests. As shown in Table III., the test was made with the same boiler that was used in testing the Jackson, O., nut coal, which gave an evaporation of 8.93. Not only were the economic results obtained from this Staunton coal very low, but the capacity of the boiler was largely reduced while using it, so that while 460 horse power had been developed, with 48 square feet of grate surface, with the Ohio coal, only 246 horse-power was obtained with 60 square feet of grate surface, with the Staunton coal. To explain this anomalous result we must turn to the analysis. It shows only 26.30 per cent. of fixed carbon, and 57.11 per cent of volatile matter, and is thus totally unlike all the other coals whose analyses are given in connection with boiler tests, the nearest approach to it being the Liverpool coal in Johnson's test, which had more than twice as much fixed carbon, and only 39.96 per cent. volatile matter. There is one coal in the list of analyses, Table II., of which, however, there is no boiler test reported, which is the only coal analysis I have found showing a higher percentage of volatile matter than the Staunton coal, and that is the Boghead coal of Linlithgowshire, Scotland, which, according to Dr. Penny, contains 67.95 per cent. of volatile matter, and only 9.54 per cent. of fixed carbon. I regret not to be able to give a complete ultimate analysis of the Staunton coal, from which to determine its theoretical heating value, but if it shows a relatively high percentage of hydrogen, and a small percentage of oxygen, nitrogen and moisture, as does the Boghead coal, then its theoretical heating power must be high, and the only reason it did not give good results in the boiler test must be that it was not properly burned. A broad distinction must be drawn here between the boiler used to absorb the heat developed from burning coal, and the furnace under the boiler in which the coal was burned. There can be no question in this case as to whether the boiler had sufficient absorbing surface, for if it could develop 460 horse power with an evaporation of 4.11 pounds water per square foot of heating surface per hour, and 8.93 pounds of water per pound of coal, it should be able with even greater economy to develop only 246 horse power, at a rate of evaporation of only 2.27 pounds of water per square foot of heating surface per

hour. If the coal had been burned in the furnace the boiler would have absorbed the heat. The conclusion is that the furnace under the boiler, or possibly the method of firing, which was well adapted to Jackson, O., coal, was not well adapted to Staunton, Ill., coal, and further experiments with various kinds of furnaces should be made to determine what furnace is best adapted to it.

This paper has already grown to sufficient length, without entering upon the subject of the character of furnace best adapted to burn the different qualities of bituminous coals. In fact there are not enough data existing for a proper treatment of this very important subject. I may briefly state that my present opinion is that almost any kind of a furnace will be found well adapted to burning anthracite coals and semi-bituminous coals containing less than 20 per cent. of volatile matter; that probably the best furnace for burning those coals which contain between 20 and 40 per cent. volatile matter, including the Scotch, English, Welsh, Nova Scotia, and the Pittsburgh and Monongahela River coals, is a plain grate-bar furnace with a fire-brick arch thrown over it, for the purpose of keeping the combustion chamber thoroughly hot; that the best furnace for coals containing over 40 per cent. volatile matter will be a furnace surrounded by fire brick with a large combustion chamber, and some special appliance for introducing *very hot* air to the gases distilled from the coal, or preferably, a separate gas producer and combustion chamber with facilities for heating both air and gas before they unite in the combustion chamber. The character of furnace to be especially avoided in burning all bituminous coals containing over 20 per cent. of volatile matter, is the ordinary furnace in which the boiler is set directly above the grate bars, or in which the heating surfaces of the boiler are directly exposed to radiation from the coal on the grate. The question of admitting air above the grate, which was favorably settled by Chas. Wye Williams forty years ago, is again unsettled. The London *Engineer* recently said: "All our experience, extending over many years, goes to show that when the production of smoke is prevented by special devices for admitting air, either there is an increase in the consumption of fuel or a diminution in the production of steam. * * * The best smoke preventer yet devised is a good fireman."

The English and French experiments on the evaporative power of bituminous coals are of little value for this country, since the coals described in these experiments were of limited variation in composition. Johnson's experiments are of little value, since they

included no bituminous coals west of Pittsburgh. Gen. Meigs' experiments are worthless, since neither of his boilers was adapted to the thorough combustion of highly bituminous coal. The Babcock and Wilcox boiler tests are valuable in showing that with proper furnace settings, very much higher results can be obtained from the highly bituminous coals than would have been believed from the experiments of Johnson and Meigs. Their great demerit is that they are not yet sufficiently extensive. Table III. gives the details of the Babcock and Wilcox tests, as far as I have been able to obtain them; this complete list has not hitherto been published. All of these tests were made with the furnace supplied with a fire-brick arch for preventing the radiation of heat from the grates directly to the boiler, and for keeping the combustion chamber hot. They were made with boilers of the same kind, and practically the same proportions, but in different parts of the world, by different experimenters, and at different rates of evaporation, caused chiefly by the different steam requirements of the establishments in which they were situated.

At the bottom of Table I., I have placed the best recorded results obtained from anthracite coal by Johnson's, Meigs', the Little Giant, and Babcock and Wilcox boilers, as a standard for comparison with the bituminous coals. The following table shows the relative value of the several bituminous coals therein named, as tested by each of the boilers, the best results being selected out of those given in Table I. and the figures for anthracite being taken at 100 per cent:

Relative Steaming Values of Bituminous Coals. Anthracite=100.

Coals.	Johnson's Boiler.	Gen. Meigs' Boiler.	Little Giant Boiler.	Babcock and Wilcox Boilers.
Newcastle, Eng.....	84.5	81.1	59.0	——
Welsh.....	——	——	——	109.6
Scotch.....	67.8	81.2	60.7	109.5
Cambria Co., Pa., semi-bit.	90.1	——	——	91.2
Somerset Co., " " "	——	105.1	97.2	——
Cumberland, Md., " "	97.5	——	96.8	——
Pittsburgh, Pa.....	80.0	96.8	76.2	99.5
Ohio.....	——	——	64.8	84.9
Vancouver Island.....	——	81.0	68.5	85.7

From the above table it will be seen that by all of the tests of the semi-bituminous coals, their value as compared with anthracite varies only from 90.1 to 105.1 per cent., confirming what has

already been said, that these coals give excellent results under a great variety of conditions. The value of the Scotch coals appears to vary between 60.7 and 109.5 per cent. of the value of anthracite, the same identical coal giving 60.7 per cent. in the Little Giant boiler, and 81.2 per cent. or more than one-third better in Gen. Meigs' boiler. The value of Pittsburgh coal is from 76.2 to 99.5 per cent. of the value of anthracite, the experiments of Gen. Meigs with one coal giving the figures 76.2 and 96.8 per cent. The relative value of bituminous coal is therefore a variable quantity, dependent upon the conditions under which it is burned.

I hope the facts here imperfectly outlined may draw attention to the possibility of obtaining better results from the highly bituminous coals of our Western States than are generally obtained in practice, or than those shown in the experiments here recorded. The whole subject of the proper methods of burning bituminous coals of various compositions needs to be re-opened. It must be studied from the bottom, beginning with both proximate and ultimate analyses of the coals, and including scientific determinations of total heating power as well as practical tests under steam boilers. The subject is of immense importance to the industries of the West and South. It would be well if the government would undertake the series of accurate experiments necessary to lead to a solution of the problems involved, but if such experiments are to be conducted as imperfectly, and the results obtained so misleading, as those reported by Gen. Meigs, they had better be left to private enterprise.

Table I.—Evaporative Power of Bituminous Coals.

Number for Reference.	Name of Coal and Location of Mine.	Percentage of Refuse by Boiler Test.	Percentage of Volatile Matter by Analysis.	Pounds of Water Evaporated Per Pound of Coal, from and at 212°.				
				Scheerer-Kestner and Meunier-Dollfus Elephant Boiler.	Prof. W. R. Johnson. Two-Flue Boiler.	Gen. M. C. Meigs. Meigs Boiler.	Gen. M. C. Meigs. Little Giant Boiler. Results divided by 0.83.	Babcock and Wilcox Boilers.
	Continent of Europe.							
1	Ronchamp.....	17.5	23.19	8.58	....	....	....	....
2	Friedrichsthal.....	18.4	33.79	7.55	....	....	....	....
3	Duttweiler.....	17.7	32.19	8.07	....	....	....	....
4	Louisenthal.....	16.9	38.42	7.18	....	....	....	....
5	Altenwald.....	16.1	31.86	8.18	....	....	....	....
6	Heinitz.....	12.6	33.98	8.14	....	....	....	....
7	Sulzbach.....	14.9	....	7.79	....	....	....	....
8	Von der Heydt.....	16.3	....	7.61	....	....	....	....
9	Blanzy, Monteeau.....	16.7	....	7.48	....	....	....	....
10	" Anthracite.....	22.9	....	7.91	....	....	....	....
11	Creusot.....	10.7	....	9.67	....	....	....	....
	England.			Delabeche and Playfair				
12	Newcastle. Av. of 18.....	....	....	8.01	....	....	....	....
13	Derbyshire and Yorkshire. Av. of 7.....	....	....	7.58	....	....	....	....
14	Lancashire. Av. of 28....	....	....	7.94	....	....	....	....
15	Liverpool.....	5.3	39.96	....	7.84	....	....	....
16	Newcastle.....	6.3	35.83	....	8.66	....	....	....
17	Davison. West Hartley....	6.0	....	....	....	7.60	....	....
18	Cowper. Newcastle-on-Tyne.....	6.1	....	....	....	7.52	6.07	....
19	Cowpen Cambois. W. Hartley	6.2	....	....	....	7.04	....	....
	Wales.							
20	Welsh. Test in London...	7.5	....	....	....	....	....	11.53
21	Cardiff Lump. Test in San Francisco. Av. of 2....	10.9	....	....	....	....	....	9.85
22	Welsh. Av. of 37.....	....	....	9.05	....	....	....	....
	Scotland.							
23	Scotch. Av. of 8.....	....	....	7.70	....	....	....	....
24	Scotch.....	10.8	39.19	....	6.95	....	....	....
25	Scotch Splint.....	6.7	....	....	....	7.61	6.25	....
26	Ardrossan, Fergushill.....	5.0	...	....	....	....	6.10	....
27	Scotch. Test at Greenock.	7.0	....	....	....	....	....	11.52
	Nova Scotia.							
28	Pictou. Av. of 2.....	12.8	26 90	....	8.63	....	....	....
29	Sidney.....	6.4	23.81	....	8.11	....	....	....

Table I.—Continued.

Number for Reference.	Name of Coal and Location of Mine.	Percentage of Refuse by Boiler Test.	Percentage of Volatile Matter by Analysis.	Pounds of Water Evaporated Per Pound of Coal, from and at 212°. Scheerer-Kestner and Meunier-Dollfus, Elephant boiler.	Prof. W. R. Johnson. Two-Flue Boiler.	Gen. M. C. Meigs. Meigs Boiler.	Gen. M. C. Meigs' Little Giant Boiler. Results divided by 0.843.	Babcock and Wilcox Boilers.
	Pennsylvania.							
30	Dauphin, Susquehanna....	16.5	13.82	....	9.34	...	....	....
31	Lycoming Creek.....	13.1	13.84	....	8.91	....	....	....
32	Blossburg.....	11.5	14.78	....	9.72	....	....	....
33	Quin's Run.....	9.3	17.97	....	10.27	....	....	....
34	Karthaus	8.0	19.53	....	9.09	....	....	....
35	Cambria Co	9.5	20.52	....	9.24	....	....	....
36	Pittsburgh.....	9.5	36.76	....	8.20	....	....	....
37	Standard C. Co., Brothers Valley, Somerset Co.....	11.0	....	....	....	9.85	10.00	....
38	Philson Iron Coal Co., Berlin, Somerset Co.....	9.1	....	....	....	9.75	....	....
39	Simpson Horner & Sons, near Pittsburgh.....	7.9	....	....	....	9.07	7.84	....
40	Thos. Fawcett & Sons, near Pittsburgh.....	6.0	....	...	....	8.78	6.74	....
41	Geo. Lysle & Sons, near Pittsburgh.....	5.5	....	....	....	....	7.62	....
42	Hornet Coal Co., near Pittsburgh.....	5.4	....	....	....	....	7.22	....
43	Powelton, 11,400 lb. mixed with 2,790 Anth. Scr'gs..	8.8	....	....	....	....	....	11.32
44	Johnstown, Cambria Co., Fine Slack.....	25.1	13.24	....	....	....	....	9.59
45	Pittsburgh, fine slack.....	12.3	....	....	....	...	....	8.12
46	" 3d Pool, lump.	4.8	....	....	....	....	....	10.47
47	Castle Shannon, near Pittsburgh, nut.....	13.0	....	....	....	....	....	8.96
48	Castle Shannon, near Pittsburgh, lump.....	9.0	31.69	....	....	...	....	10.13
49	Castle Shannon, near Pittsburgh, $\frac{3}{4}$ nut, $\frac{5}{8}$ lump....	10.5	....	....	....	....	....	10.00
	Maryland.							
50	Cumberl'd, Blan. Avon Mine	8.3	....	....	....	....	9 96	....
51	Av. of 5 Md. Free-burning bit.....	11.03	14.21	....	9.99	...	....	....
52	Cumberland.....	8.25	...	Isherwood. 9.69	....	....	....	....
	Virginia.							
53	Average of 10 Coking Coals, near Richmond....	11.47	30.36	....	8.59	....	....	....
	West Virginia.							
54	W. Va. Splint, Paint Creek, W. Va.....	8.1	....	....	....	8.34	8.34	....

Table I.—Continued.

Number for Reference.	Name of Coal and Location of Mine.	Percentage of Refuse by Boiler Test.	Percentage of Volatile Matter by Analysis.	Pounds of Water Evaporated Per Pound of Coal, from and at 212°.				
				Scheerer-Kestner and Mennier-Dollfus, Elephant Boiler.	Prof. W. R. Johnson, Two-Flue Boiler.	Gen. M. C. Meigs, Meigs Boiler.	Gen. M. C. Meigs' Little Giant Boiler. Results divided by 0.843.	Babcock and Wilcox Boilers.
	Tennessee.							
55	Battle Creek, South Pittsburgh	6.6	....	....	....	....	6.76	....
56	Coal Creek, near Knoxville	5.6	....	....	....	....	6.75	....
	Ohio.							
57	Kyle Coal Co., S. E. of Youngstown	4.8	....	....	....	....	6.82	....
58	Vienna C. & I. Co.	6.1	....	....	....	....	6.71	....
59	Hubbard Mine	5.1	....	....	....	....	5.98	....
60	Jackson Co., nut	9.6	....	....	....	....	....	8.93
	Indiana.							
61	Ind'a Cannel, Daviess Co.	24.8	....	....	....	7.32	7.12	....
62	Indiana Block	....	....	....	....	....	....	9.47
	Illinois.							
63	Illinois "Run of Mine"	....	....	....	....	....	....	9.49
64	Staunton, fine nut	17.7	57.11	....	....	....	....	5.09
	Missouri.							
65	Lexington Coal Shaft	12.2	....	....	....	....	6.51	....
	Nebraska.							
66	Rocky Mountain. Rocky Spring Mine	6.5	....	....	....	6.01	4.93	....
	Kansas.							
67	Leavenworth Coal Shaft	11.1	....	....	....	6.49	6.42	....
	Indian Territory.							
68	Macallester, Tobosky Co.	5.8	....	....	....	7.68	6.96	....
	Texas.							
69	San Antonio Mining Co., near S. A.	11.5	....	....	....	....	4.46	....
	Colorado.							
70	Mitchell & Co., La Plata, near Ft. Lewis	10.9	....	....	...	7.49	....	....
71	Canon Coal, Fremont Co.	10.	....	....	...	6.45	6.01	....
72	Trinidad, Starksville	14.8	....	....	....	....	8.59	....
73	El Moro, near Trinidad	15.8	....	....	....	....	8.04	....
	New Mexico.							
74	Los Cerillos bit., Ortez Grant	13.3	....	....	....	8.60	...	....

Table I.—Continued.

Number for Reference.	Name of Coal and Location of Mine.	Percentage of Refuse by Boiler Test.	Percentage of Volatile Matter by Analysis.	Pounds of Water Evaporated Per Pound of Coal, from and at 212°.				
				Scheerer-Kestner and Meunier-Dollfus. Elephant Boiler.	Prof. W. R. Johnson. Two-Flue Boiler.	Gen. M. C. Meigs. Meigs Boiler.	Gen. M. C. Meigs' Little Giant Boiler Results divided by 0.83.	Babcock and Wilcox Boilers.
	Utah.							
75	Weber, Chalk River, Summit Co.	10.	....	....	....	4.73	3.79	....
	Dakota.							
76	Lignite, Fort Stevenson...	6.2	....	....	....	4.03	4.47	....
	Montana.							
77	Chestnut Mine, Rock Creek Canon.	32.4	....	....	....	6.07	6.15	....
	California.							
78	Pittsburg, Mt. Diablo Mine, Somersville	11.	....	....	....	5.05	4.34	...
	Pacific Coast Brown Coals.							
79	Wahsatch Range, Mt. Diablo, Cal. Coos Bay, Oregon, Seattle, W. T. Av'ge.	13.18	....	Isherwood. 5.99	....	....	....	....
	Oregon.							
80	Eastport, Coos Bay	8.8	....	....	....	5.24	5.13	....
	Washington Territory.							
81	Brown Coal, Bellingham Bay	23.48	....	6.13	....	....	....	....
82	Seattle screenings	13.4	....	....	....	....	....	6.86
83	" " wet	10.7	....	....	....	....	....	7.46
84	" lump	9.5	....	....	....	....	....	6.68
	Vancouver's Island.							
85	South Wellington, Departure Bay	8.2	....	....	....	7.59	7.07	....
86	Nanaimo, Chase River	13.2	....	....	....	7.30	6.60	....
87	Wellington, Departure Bay	9.4	....	....	....	6.71	6.69	....
88	" screenings	18.3	....	...	...	....	....	7.89
89	" lump	13.8	....	....	....	....	....	9.02
90	East Welli'gton, screenings	16.8	....	....	....	....	....	7.80
91	Brown Coal, Nanaimo	12.7	....	7.36	....	....	....	....
	New South Wales.							
92	Wallsend, Sydney, Newcastle	8.8	....	....	....	....	7.11	....

Table I.—Concluded.

BEST PENNA. ANTHRACITE PERFORMANCE FOR COMPARISON.

NAME OF COAL AND LOCATION OF MINE.	PERCENTAGE OF REFUSE BY BOILER TEST.	PERCENTAGE OF VOLATILE MATTER BY ANALYSIS.	POUNDS OF WATER EVAPORATED PER POUND OF COAL, FROM AND AT 212°.				
			Scheerer-Kestner and Meunier-Dollfus, Elephant Boiler.	Prof. W. R. Johnson, Two-Flue Boiler.	Gen. M. C. Meigs, Meigs Boiler.	Gen M. C. Meigs' Little Giant Boiler. Results divided by 0.843.	Babcock and Wilcox Boilers.
Forest Improvem't, Schuylkill Co.	7.0	....	....	10.25	....	....	....
Forest Improvem't, Schuylkill Co	20.6	....	....	....	9.37	....	....
Forest Improvem't, Schuylkill Co.	13.5	....	....	....	....	10.29	....
Lea Colliery, Wilkesbarre.	11.0	....	....	....	....	....	10.52

Table II.—Analyses of Bituminous Coals.

Corresponding Number in Table I.	Name of Coal.	Carbon.	Hydrogen.	Nitrogen and Oxygen.	Moisture.	Ash.	Fixed Carbon.	Volatile Matter.	Authority.
	Contin't of Europe.								
1	Ronchamp.....	76.23	4.06	1. 5 91	....	12.8	58.01	29.19	Kestner & Dollfus.
2	Friedrichsthal....	67.81	4.19	0.5 13.8	1.	12.7	47.51	33.79	"
3	Duttweiler.....	71.25	4.1	0.5 9.15	1.75	13.25	44.51	32.19	"
4	Louisenthal.....	64.69	3.94	0.5 15.02	3.87	12.38	49.19	38.42	"
5	Altenwald.....	69.3	4.26	0.5 9.9	2.54	13.5	54.62	31.86	"
6	Heinitz.....	70.33	4.3	0.5 11.51	1.79	11.57	54.45	33.98	"
7	Sulzbach.....	74.36	4.43	10.75	....	10.46	....	....	"
8	Von der Heydt....	73.03	4.46	12.05	....	10.46	....	....	"
9	Blanzy, Montceau.	70.50	4.69	14.53	....	10.28	....	....	"
10	" Anthracite	68.79	3.73	6.53	....	20.95	....	....	"
11	Crensot.....	86.74	3.95	4.94	....	3.63	....	....	"
	England, Scotland and Wales.								
12	N'wc'tle, Av. of 18	82.12	5.31	1.35 5.69	....	3.77	....	....	Delabeche & Playfair.
13	Derbyshire & Yorkshire, Av. of 7..	79.68	4.94	1.41 10.28	....	2.65	....	....	"
14	Lancashire, Av. of 28.....	77.90	5.32	1.30 9.53	....	4.88	....	....	"
15	Liverpool.....	....	....	....	.89	4.62	54.9	39.96	Johnson.
16	Newcastle	....	....	....	2.01	5.4	57.	35.83	"
22	Welsh, Av. of 37.	83.78	4.79	0.98 4.15	....	4.91	....	....	Delabeche & Playfair.
23	Scotch, Av. of 8...	78.53	5.61	1.00 9.69	....	4.03	....	....	"
24	Scotch.....	....	....	....	3.01	9.34	48.81	39.19	Johnson.
	Glasgow, Av. of Splint and Cherry.	82.06	5.47	11.19	....	1.28	....	....	Dr. Richardson.
	Boghead, Linlithgowshire.....	63.94	8.86	0.96 4.70	0.84	21.4	9.54	67.95	Dr. Penny.
	Nova Scotia.								
28	Pictou, Av. of 2...	....	....	....	1.68	12.95	58.86	26.90	Johnson.
29	Sidney.....	....	....	....	3.13	5.49	67.57	23.81	"
	Pennsylvania.								
30	Dauphin and Susquehanna.....	....	....	....	.45	11.79	74.24	13.82	"
31	Lycoming Creek...	....	....	....	.67	13.96	71.53	13.84	"
32	Blossburg.....	....	....	....	1.34	10.77	73.11	14 78	"
33	Quin's Run.....	....	....	....	.84	8.41	72.79	17.97	"
34	Karthaus.....	....	....	....	1.28	7.00	73.77	19.53	"
35	Cambria Co.....	....	....	....	2.46	9.15	69.37	20.52	"
36	Pittsburgh.....	....	....	....	1.4	7.07	54.93	36.76	"

Table II.—Continued.

Corresponding Number in Table I.	Name of Coal.	Carbon.	Hydrogen.	Nitrogen and Oxygen.		Moisture.	Ash.	Fixed Carbon.	Volatile Matter.	Authority.
44	Johnstown, Cambria Co.	....	....	....	....	0.79	8.07	77.90	13.24	Hunt and Clapp.
48	Castle Shannon, near Pittsburgh..	....	....	....	....	1.51	3.92	62.88	31.69	"
	Pittsburgh, "Cincinnati Smoke-prevention tests"....	....	....	....	....	2.31	3.04	61.03	32.75	B. Kniffler
	Maryland.									
51	Av. of 5. Free-burning bit'm'n's.	....	....	....	....	1.25	9.49	75.45	14.21	Johnson.
52	Cumberland.....	80.55	4.50	1.08	2.70	1.75	8.25	....	....	Isherwood.
	Virginia.									
53	Av. of 10 Coking coals, near Richmond.	....	....	....	....	1.62	10.58	58.30	30.36	Johnson.
	Illinois.									
64	Staunton, Fine nut	....	....	....	....	6.27	10.32	26.30	57.11	Hunt and Clapp.
	Pacific Coast.									
79	Av. of 4 Brown Coals.....	50.05	3.85	0.91	13.65	16.82	13.18	....	....	Isherwood.
	Washington Ter'y.									
81	Brown Coal, Bellingham Bay.....	49.60	3.39	0.83	8.96	12.52	23.48	....	....	"
	Vancouver's Isl'nd.									
91	Brown Coal, Nanaimo.....	59.68	4.08	1.00	10.78	10.26	12.74	....	....	"

Table III.—Evaporative Power of Bituminous Coals.—Tests with Babcock & Wilcox Boilers.

No.	Date of Test.	Place of Test.	Name of Coal.	Duration of Test.	Average Temperature of Feed—Degrees.	Average Steam Pressure—Pounds.	Grate Surface—Square Feet.	Heating Surface—Square Feet.	Pounds of Coal Burned.	Percentage of Refuse.	Coal Burned per Square Foot of Grate—Pounds.	Water Evaporated—Pounds.	Water Evaporated per Sq're Foot of Heating Surface per Hour—Pounds.	Water per Pound Coal from and at 212 Degrees—Lbs.	Water per Pound Combustible from and at 212 Degrees.	Rated Horse Power.	Horse Power Developed.
1	Oct. 30, 1882.	London, England.	Welsh	12½ hours.	130	67	40.	1679	3,360	7.5	6.3	34,800	2.07	11.53	12.46	146	96
2	Nov. 14, 1882.	Greenock, Scotland.	Scotch	3 hours.	156	36	25.	1403	1,344	7.0	13.7	14,426	2.78	11.52	12.38	122	129
3	Dec. 15, 1882.	Peacedale, R. I.	Anthracite screenings, 2790 lb. Powelton, Pa., Bituminous, 11,400 lb.	10¼ hours.	38	77	60.	3126	14,359	8.8	17.6	133,096	4.32	11.32	12.42	272	448
4	July 19, 1882.	Cincinnati, Ohio	Pittsburgh fine slack	4 hours.	74	52	33.7	1679	7,365	12.3	21.9	51,459	4.47	8.12	9.29	146	250
5	Sept. 7, 1882.	" "	Pittsburgh, 3d Pool lump	10 hours.	132	64	43.5	2760	12,000	4.8	27.5	112,663	4.76	10.47	11.00	240	419
6	March 12, 1883.	Pittsburgh, Pa	Castle Shannon, near Pittsburgh, nut	6¼ hours.	37	95	69.1	4784	13,000	13.	27.9	95,286	3.63	8.96	10.29	416	556
7	Mar. 13–15, 1883.	" "	Castle Shannon, near Pittsburgh, lump	25½ hours.	37	95	69.1	4784	39,900	9.	22.9	330,533	3.44	10.13	11.13	416	504
8	Mar. 15–17, 1883.	" "	Castle Shannon, near Pittsburgh, ¾ nut, ¼ lump	42½ hours.	37	95	69.1	4784	83,524	10.5	27.9	683,956	4.13	10.00	11.17	416	570
9	Sept. 18–23, 1882.	Chicago, Ill	Illinois "run of mine."	6 days	190	75	....	1196	10,675	....	....	95,940	1.41	9.49	....	104	54
10	Jan. 8–10, 1883.	" "	Indiana block, "very good."	3 days	190	85	....	1196	11,150	....	....	99,676	2.95	9.47	....	104	111
11	Dec. 14, 1882.	Springfield, Ohio	Jackson, Ohio, nut.	8 hours.	117	90	48.	3358	12,338	9.6	32.1	97,024	4.11	8.93	9.88	292	460
12	May 2, 1883.	" "	Staunton, Ill., fine nut	8 hours.	155	97	60.	3358	12,034	17.7	25.1	55,614	2.27	5.09	6.19	292	246
13	May 28, 1883.	Johnstown, Pa.	Johnstown, fine slack	7¾ hours.	90	80	51.	3126	6,175	25.1	15.6	50,906	2.44	9.59	12.80	272	246
13	Febru'y 10, 1883.	San Francisco, Cal.	Renton screenings	5 hrs. 50 min.	56	106	21.2	1564	3,910	13.8	31.5	22,266	2.95	6.88	7.98	136	151
15	" 12, "	" " "	" "	6 hours.	57	99	21.2	1564	4,346	23.	34.8	24,282	3.12	6.71	8.71	136	161
16	" 13, "	" " "	Wellington screenings	6 hrs. 30 min.	57	110	21.2	1564	3,740	18.3	27.	24,547	2.93	7.89	9.66	136	150
17	" 16, "	" " "	Ea-t Wellington screenings	6 hours.	57	107	21.2	1564	3,740	16.8	29.3	24,282	3.11	7.80	9.38	136	160
18	" 17, "	" " "	Black Diamond screenings	5 hrs. 58 min.	57	107	21.2	1564	4,640	19.3	36.4	24,282	3.11	6.29	7.80	136	160
19	" 19, "	" " "	Seattle screenings	6 hrs. 24 min.	58	116	21.2	1564	4,260	13.4	31.3	24,282	2.91	6.86	7.92	136	150
20	" 20, "	" " "	Wellington lump	6 hrs. 19 min.	59	119	21.2	1564	3,777	13.8	28.2	28,329	3.52	9.02	10.46	136	171
21	" 21, "	" " "	Seattle screenings, wet	6 hours.	60	119	21.2	1564	3,915	10.7	30.7	24,282	3.11	7.46	8.35	136	160
22	" 22, "	" " "	Cardiff lump	6 hrs. 47 min.	60	114	21.2	1564	3,863	11.7	26.7	32,376	3.69	10.07	11.40	136	189
23	" 27, "	" " "	" "	7 hrs. 23 min.	62	117	21.2	1564	4,032	19.1	25.6	32,376	3.35	9.62	11.89	136	174
24	" 28, "	" " "	South Paine lump	6 hrs. 35 min.	62	118	21.2	1564	4,059	13.9	28.9	30,345	3.53	8.96	10.41	136	182
25	March 1, 1883.	" " "	Seattle lump	6 hrs. 5 min.	63	118	21.2	1564	4,420	9.5	34.1	28,329	3.57	7.68	8.49	136	184

BALANCED VALVES.

BY

C. C. COLLINS.

I DO not propose to give an exhaustive statement of the various styles of "balanced valves," but simply to present a few facts in my experience with what may be called the "Pressure Plate Balanced Valve." I suppose, without doubt, the "piston valve" patented by D. T. Davis is the mostly perfectly balanced of any slide valve; but, unfortunately, like everything else, it is subject to wear,

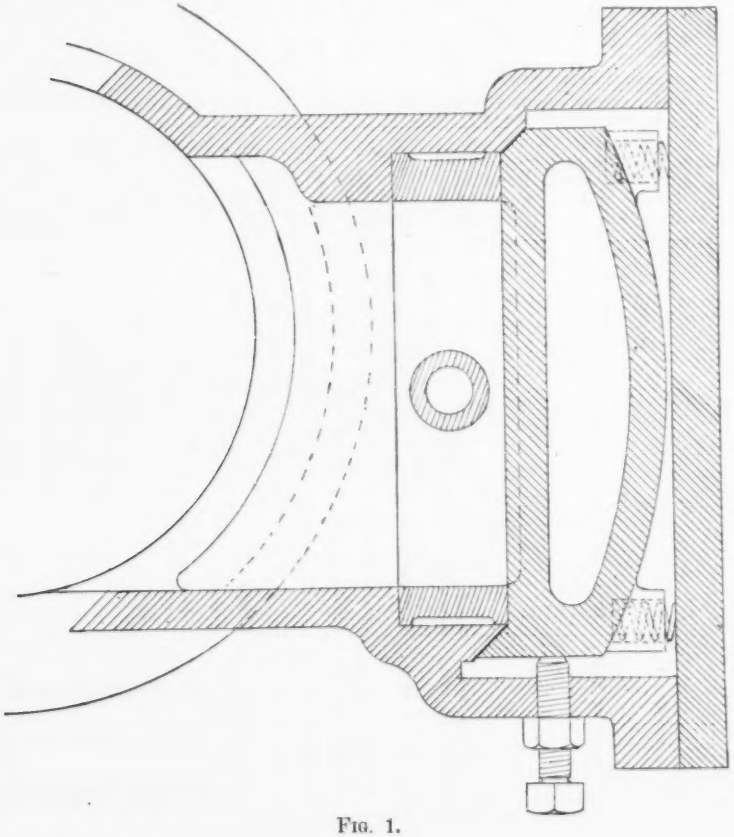


FIG. 1.

and when worn it leaks and becomes very wasteful of steam. A great many devices have been resorted to to keep the *rings* in contact with the wall of the valve chamber, but none have proved successful. Probably the best method is to bore the valve chamber as accurately as possible, make a good fit of a "plug valve," and when worn so as to leak, then re-bore and fit new valves.

In these sketches I have shown, first, a section through valve seat, valve and pressure plate of what is known as the Porter-Allen valve. This shows the method of holding the "pressure plate" so as to allow the valve to move freely between it and valve seat, and yet not permit the leakage of steam. This, you will observe, is

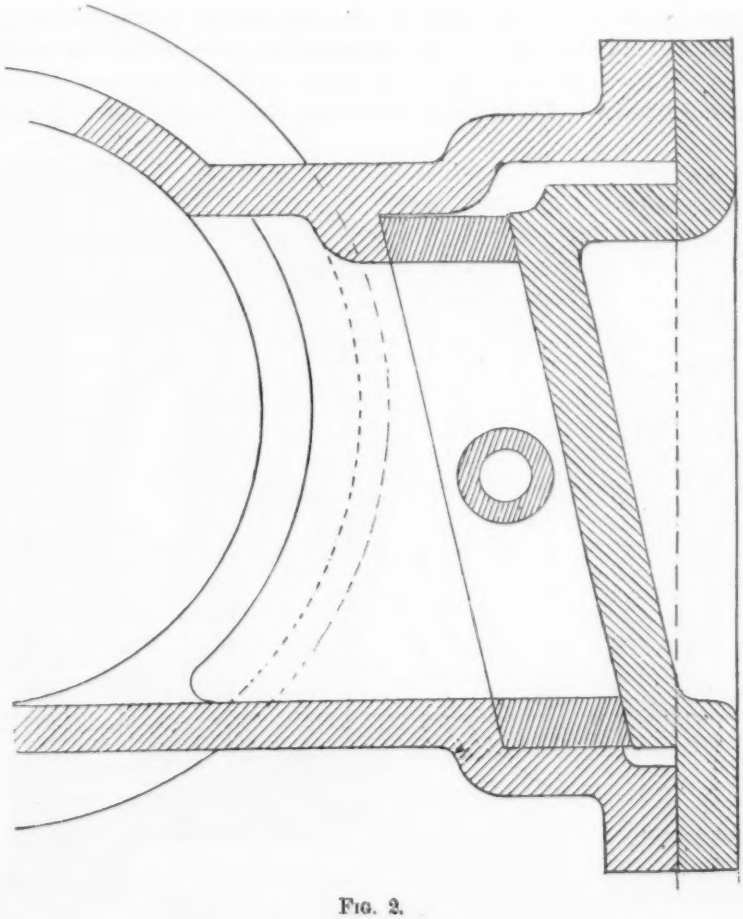


FIG. 2.

done by means of the inclines at the top and bottom of valve and set screw passing through bottom of steam chest. These inclines are at an angle of 45°. The plate is held against them by springs, and by the pressure of steam at back.

If the plate be raised by means of the set screws, it will be forced out from contact with valve by means of the inclines. This device has proved effectual, subject however, to derangement by unskillful adjustment.

Sketch No. 2, is a device of John F. Allen, and is used by Hewes & Phillips, of Newark, N. J., in the Allen High-speed Engine which they build. You will notice that the valve seat is on an incline, and that the "pressure plate" is one piece with the steam chest cover, and comes in contact with the surface of valve. This can only be adjusted by slacking the nuts, which hold the cover in place, and moving it up or down, involving great risk of misadjustment. It has also another bad feature—not allowing any

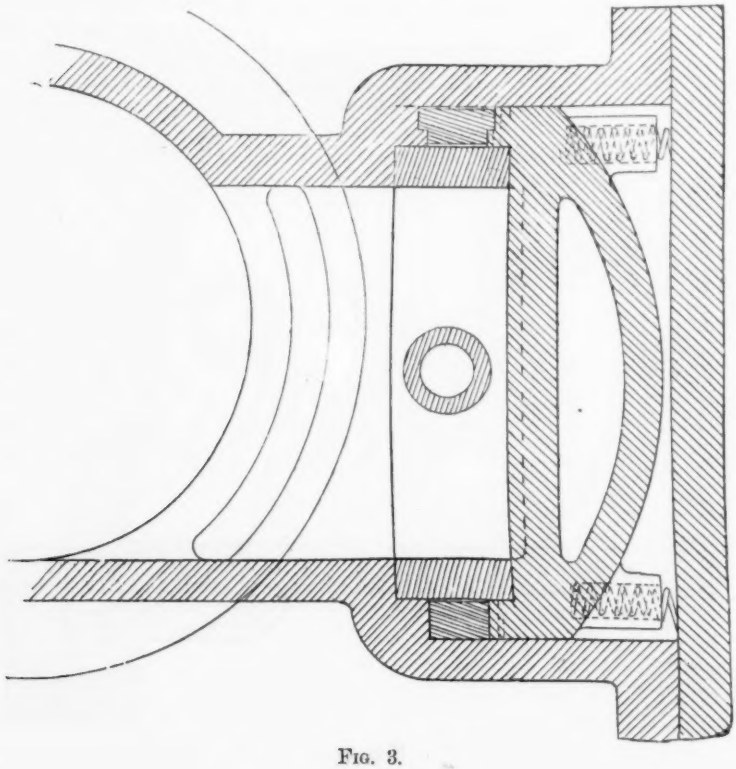


FIG. 3.

lift of the valve should water be trapped in cylinder. I was in the employ of this firm when their first engine of this style was in progress of construction, but left them before it was completed, but have been informed that they were obliged to put relief valves on the cylinder after it was in operation.

Sketch No. 3 is a modification of the "pressure plate" and valve as used by Prof. Sweet. Prof. Sweet uses a plain strip between the "plate" and valve seat at top and bottom, so as to allow free movement of valve between them. I make these strips long wedges, and adjust by means of set screws through walls of steam chest. The only objection to this is, that it allows of manipulation by an unskillful engineer. In a large majority of cases it has proven very satisfactory. I have also used the plate by simply letting it bear against shoulders in steam chest, properly arranged and scraped to a good fit.

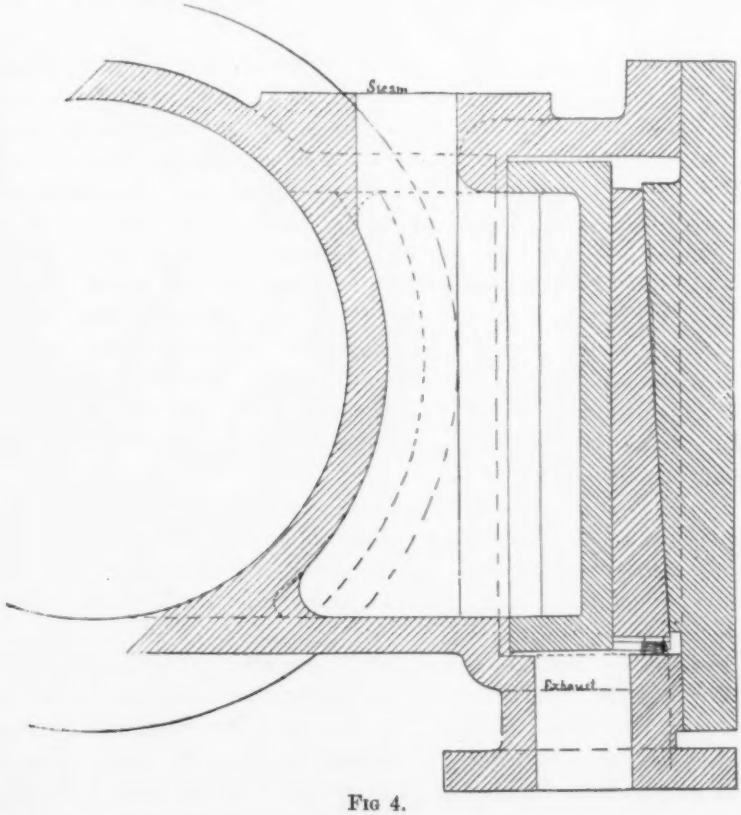


Fig 4.

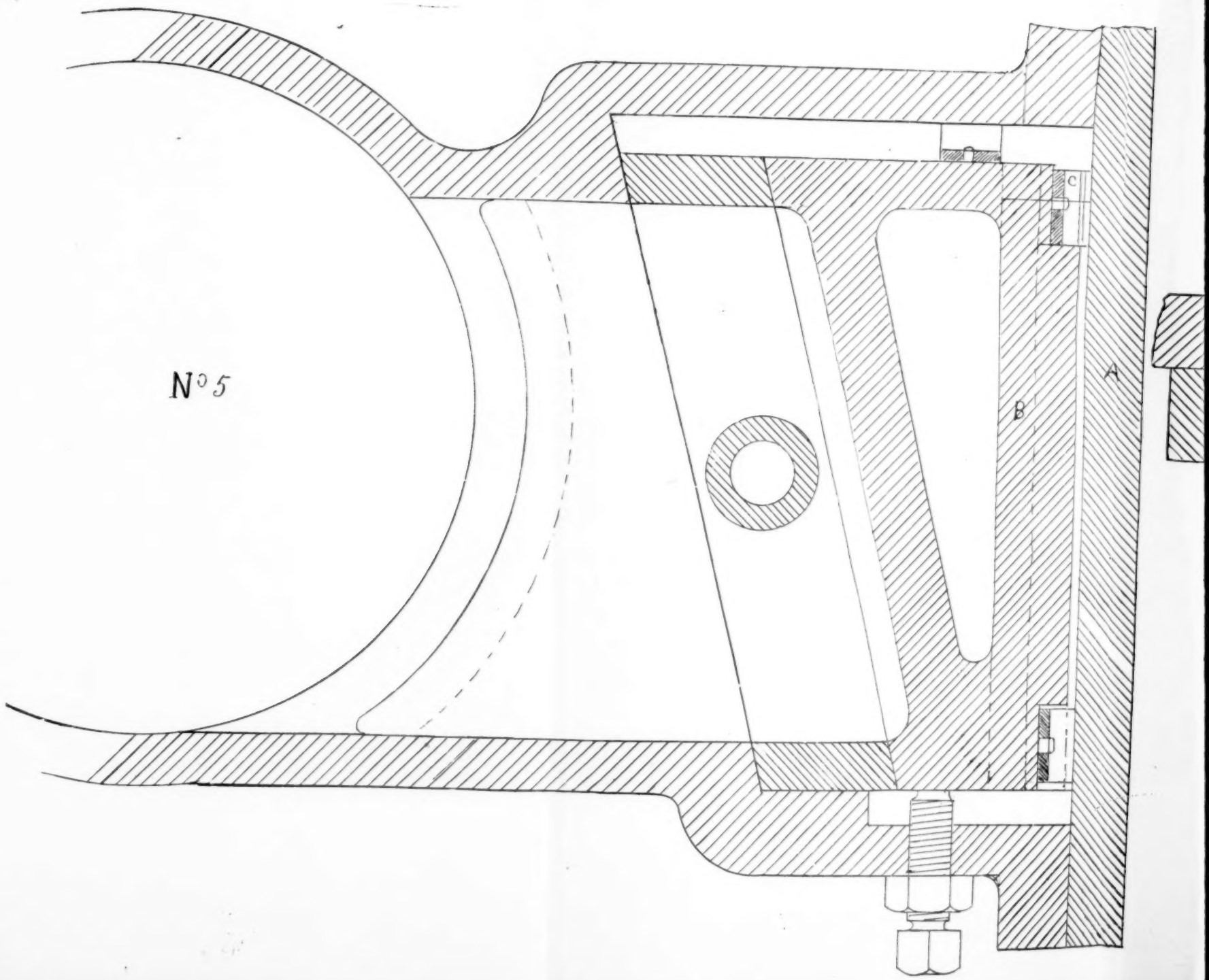
There is an engine in this city (Cleveland) which has its steam chest on top of cylinder; the valve is 18″ × 23″. It was desired to relieve the enormous load due to so large a valve. I put in a "pressure plate," with the long, thin wedges at the sides, adjusted by set screws at each end. To get depth of chest to accommodate this "pressure plate" I cast a thick copper gasket to go between top of steam chest and cover. This arrangement has given entire satisfaction.

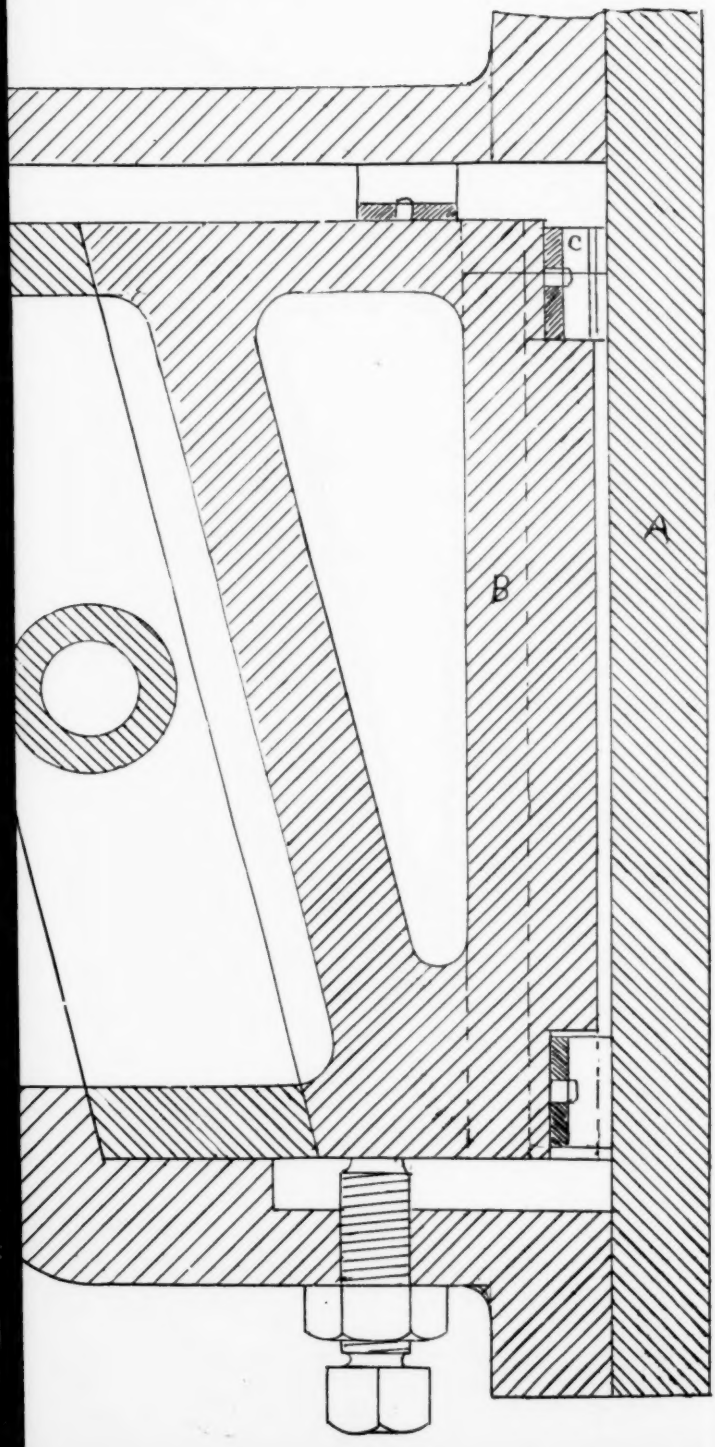
Sketch No. 4, is an arrangement which I put into an engine of 10″ bore and 16″ stroke. You will notice that the steam is admitted into the interior of valve and exhausts into steam chest and passes out of bottom of same. The valve is provided with a wedge at back to keep valve to its seat. This is subject to the same objection as the Allen valve, and the cylinder is provided at each end with a relief valve. This engine has been running continuously night and day since October, 1881, and has never given any trouble.

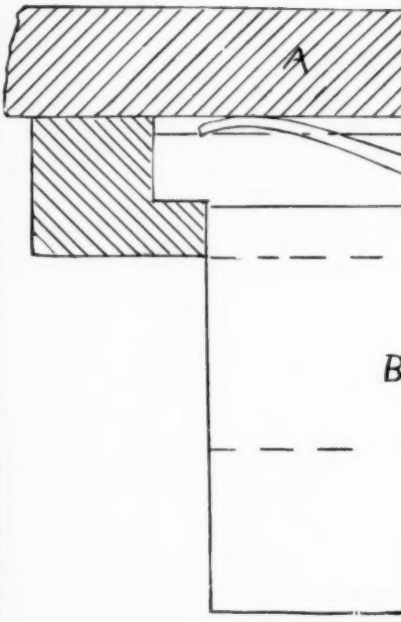
Sketch No. 5 is an attempt to construct a valve which shall have all the advantages of Mr. Allen's without any of its drawbacks. It is adjusted by setting the valve seat at an angle and introducing a wedge-shaped "pressure plate" between valve and steam chest cover; this plate has lips which rest in channels or grooves, formed on inside of steam chest cover in such manner that a space is left between plate and cover, and yet the plate cannot bind the valve to hinder its free movement; by this means the valve can lift from its seat should any water be trapped in cylinder. This "plate" is adjusted by means of set screws at the bottom. This valve arrangement was placed in an engine of 18″ bore and 36″ stroke, and was subject to very hard usage, so that it has never given perfect satisfaction, owing to its being constantly adjusted by the attendants, and the character of some of these may be seen by the following incident:

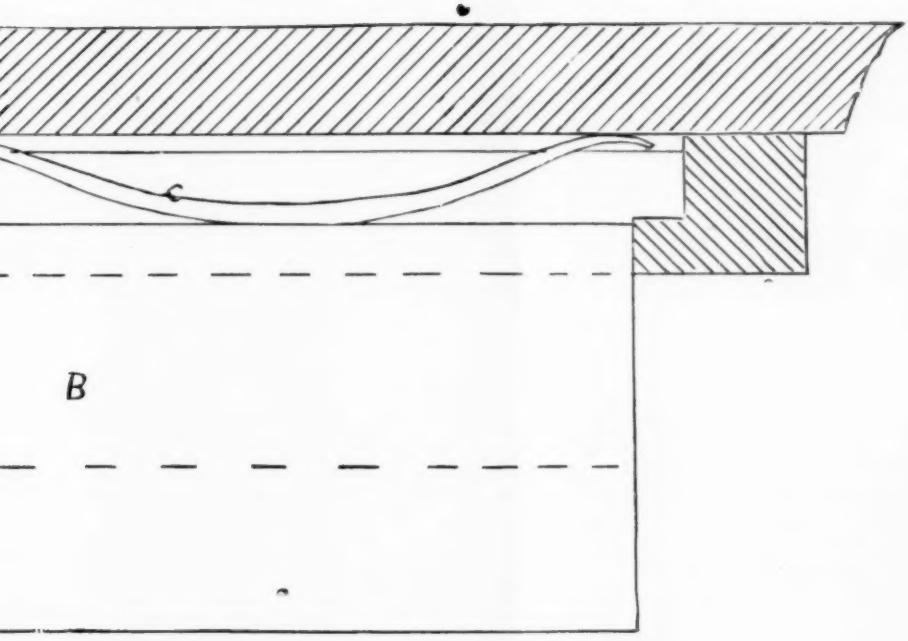
I found, on going into the engine-room one day, the crank pin was warming, and asked the engineer the cause. *He did not know*, but I found he had removed the automatic oiler and filled the cavity in crank pin with hard soap, saying, "he had heard that soap was a good lubricant."

In investigating the causes why so frequently this class of valve will run well for a long time and then, when adjustment is attempted, it is almost impossible to secure good results until quite a period has elapsed after the adjustment is made, I have found that where the movement of pressure plate for the purpose of ad-


N° 5
A
B
C


C
A
B


A
B


B

justment is *across* the valve, it disturbs the agreement between the surfaces of plate and valve. After running a while it will be found that both valve and plate are worn uneven, frequently in ridges, and so any movement brings into bearing new parts, and leaves open spaces where steam will pass. When, however, the plate is moved directly in upon the valve, as in the valve shown in Sketch No. 3, or in Prof. Sweet's method, this difficulty is not encountered. The best results are obtained when the pressure plate is so arranged that it cannot be manipulated by the person in charge of the engine, but when it is found necessary from any cause to readjust, it should be put into the hands of competent men, who should put it in the same condition as at the first.

I have also found that it will not do to send engines out with "pressure plate balanced valves" which have never been scraped after being heated under steam, as, no matter how carefully they may have been fitted in the first place, both plate and valve will distort, and hence trouble ensue, and sometimes the process of scraping to a fit has to be repeated several times before a fit will be obtained which will remain. Again, trouble has arisen from the weakness of the plate; this should be of the most rigid character, so that when under steam there may not be the least tendency to spring in centre and so bind the valve.

If these precautions are observed, this class of valve will satisfy all reasonable expectations.

ON STANDARD CAST-IRON FITTINGS.

BY

WILLIAM J. BALDWIN, NEW YORK.

THE absolute and positive necessity for uniformity in cast-iron fittings for wrought iron pipes, prompts me to take an interest in a work which evidently was commenced by the late Robert Briggs, of Philadelphia, a member of the Institute of Civil Engineers, and known professionally to many here.

In a posthumous paper ("American Practice in Warming Buildings by Steam") and I believe his last contribution to Science, which was read before the Institute of Civil Engineers in England (Session 1882–83, Part I.), he gives many valuable *data* relating to wrought iron pipe-threads and fittings and introduces a scale for dimensions of cast-iron fittings which does away with needlessly complicated formulæ, giving by simple straight lines the necessary measurements for laying out all sized fittings—(Elbows or Tees) from $\frac{1}{8}$th of an inch to 8 inches, inclusive.

He had much to do with giving character and form to the present merchantable fittings and valves, and deplored—for none knew better than he—the condition into which competition in prices was degenerating a branch of industry which may be said to be purely American.

Wrought iron pipe is standard in size because it cannot well be otherwise, and the only way it can be varied is in the thickness of the iron from which it is made, as the outer diameter must be sufficiently exact to fit within the guide-bushings of the stocks and dies and at the same time give a full thread—this fact always keeping the pipe sufficiently near the standard to be practical.

But with fittings, more especially cast-iron ones, the only thing which can be said to be standard about them, is the thread—and *it* is not standard with many makers, except in so far as the diameter at the outer edge of the thread is concerned—the rest of the thread being parallel.

When the cast-iron fitting was first made—wrought-iron, brass, and malleable iron being previously in general use—it was supposed from the generally considered friable nature of the metal, that the

fittings would be easily broken—hence sizes and proportions were adopted which were positively ample and which later experience proved to be heavier than was actually necessary for ordinary purposes.

This led to a reduction to sizes and shapes, which, though different manufacturers varied somewhat, were, and are now, pronounced "good fittings"—meaning that they were sufficiently heavy, so as not to split with ordinary manipulation and called for no anxiety on the part of the workman about the permanency of his construction.

But these fittings, when at their best, were alike only in their *nominal distinction*—their length and radii being as various as there were manufacturers; and not infrequently different patterns by the same maker were in the market.

Gradually, as the manufacture became more important, *prices* which at first gave an ample profit, and which called for no retrenchment on the part of the maker, were reduced by those who were eager to increase their sales, and which, as long as they put an equally good fitting on the market, were perfectly justified by the laws of trade. But the result was as should be expected with a commodity that had no *standard quality*.

Manufacturers—some of them against their judgment—began to lighten their fittings, so as to be able to meet the market at a profit. The general result was—as light a fitting as would possibly stand screwing up, leaving no factor for safety.

But this was not all. Fittings had to weigh less still to make a profit on them, and as they had reached the minimum in thickness, they had to be shortened in radius—in what is called "the length from the centre,"—the length of the "hub," and the length of the inside of the hub in which the thread is cut, until the inside thread of a fitting is shorter than the length of an ordinary thread on a pipe, allowing the end of the pipe to screw past the thread in the fitting. In fact, the fitting may be said to have reached the ultimate degree of attenuation and stunting it will bear.

The use of the "straight tap" is also to be condemned.

With fittings of certain sizes (below 2″) it is found that they can be molded and cast sufficiently accurate so that they can be tapped without reaming; but it has also been found that the "skin" of the casting spoils a tap rapidly. This led to the use of a long tap with parallel sides, which can be ground backward from the point —the point always forming a reamer below the first tooth of the

tap—and as the tap is fed to its work by a lead screw of corresponding pitch, it can be forced into the fitting.

The reason why fittings should not be threaded with a parallel tap is obvious, and requires no further comment from me; but I will say, another inducement to use the "straight tap" is the decreased power necessary to operate it.

The objections to present fittings may be summed as follows:

I. The greater part of them are too light.

II. The radius is frequently too short.

III. Elbows, tees, and crosses of the same maker have generally *not* the same length from ends to centres.

IV. Fittings of the same denomination from different makers, do not agree in length and radius.

V. Many fittings are tapped straight.

VI. Inaccuracy in the shape and taper of threads.

VII. A tee or cross will not go *in* where an elbow came *out* without changing the length of the pipes.

VIII. Tees of a given *prime* denomination have not the same lengths.

IX. Crosses of a given *prime denomination* have not always the same length.

X. Tees and crosses, in their *secondary denominations*, have not the same length from centres to ends of branches, for the same *primary* denominations, nor do tees and crosses agree with each other.

XI. A reducing elbow has not the same measurements as a reducing tee of the same general denomination.

XII. There is no simple method by which a person cutting pipes can always find what has to be allowed, when he is given centre measurements, if he has not the fittings in his possession.*

RECOMMENDATIONS FOR STANDARD FITTINGS.

I. That a minimum thickness of metal be established for the different parts of a fitting, according to its *prime* denomination, above

* It should be here explained, for those not versed in the technicalities of the fitting trade, that in calling or denominating a fitting, the way a fluid will flow for *distribution* must be borne in mind, and the sizes of openings given in the order of their magnitude, commencing with the greatest and going straight through the fitting in the direction of the flow, first. The largest opening of a fitting is the prime denomination: with a single exception in what is called a "bull headed tee"—one whose side branch, or opening, is the largest: when the smaller sizes in a direct line are mentioned first.

which makers may go if they desire, but below which the fitting *will not be standard.*

II. That the radius of a fitting be fixed, and that it shall bear some *common relation* to the diameter of the pipe.

III. That elbows, tees, and crosses of the same prime denomination shall have the same lengths from *centres to ends of hubs.*

IV. That the length of a fitting from its centre to the end of the hub bear some *common relation* to the *diameter* of the pipe.

V. That a standard fitting must have a standard weight, below which it *must not* go.

VI. That all fittings be tapped with a *taper* thread of 1 in 32 to the axis of the openings — $\frac{1}{16}$ of an inch to one inch in length of thread—and that the present established method, which is not accurate, though capable of maintaining a practical uniformity in diameters, be retained until such time as methods founded on the "Standard Gauge System" be adopted.

VII. That a minimum length of thread be established for fittings in proportion to the size of the pipe, below which they will not be standard.

The use of scales for fitting and valve-making—one of which, for elbows and tees, is represented in the accompanying cut—was due to Robert Briggs.

His practice was to have these scales engraved or heavily scratched on brass or copper plates from which the dimensions of fittings of any desired size could be taken at once with a dividers by the pattern-maker, without tedious calculation, and without having to furnish him with working drawings, and preventing a possibility of change in dimensions or design.

The explanation of the scale I will give in his own words, namely:

"In regard to the construction of the scale shown in the diagram, the ordinates, though here headed for convenience with the nominal inside diameters of the tubes, are spaced from the zero point at horizontal distances (*half* full size) equal to the actual outside diameters of wrought iron pipe. Of the slant lines, only two pass through the origin or zero point: namely, the line for the internal radius *R* of the back of the elbow, and the line giving the dimension *A*, which is exactly half the radius *R*. Of the remaining lines, those giving the three dimensions *B*, *D*, *C*, intersect the base line a little to the left of the origin or zero point, which means that each of the three dimensions given by these lines contains some small increment in excess of the dimensions that would be strictly proportional.

For instance, with regard to the thickness *C* at the back of the elbow, it is evident that, if the metal in any casting, whether small or large, thin or thick, were truly homogeneous throughout both its skin and its interior portion, this thickness should then be strictly proportional to the diameter or radius of the bore; but for small castings a certain allowance of extra thickness is needed, in order to insure soundness, as well as to compensate for the increased brittleness of thin cast-iron. There will, however, be some size of fitting, for which the normal strength of metal may safely be assumed, and for which, therefore, no extra thickness will be needed. On this assumption the thickness for the largest size is set out at the end of the scale farthest from the origin; while nearest to the origin is set out the thickness proper for the smallest size, in which the increment is at its maximum; and the slanting straight line drawn between these two extremes gives for intermediate sizes an increment which varies inversely as the diameter or radius. Needlessly complicated formulæ, involving higher or lower powers of the diameter, are thus replaced by the simple straight line. In the two bottom lines, *L* and *F*, pertaining to the screwed portions of the fitting, which are a function of the pitch, the irregularities of slope are due to the fact already commented upon, that the pitch of the screw thread for different diameters of tube proceeds by a medley of arbitrary jumps, instead of by a steady progression concordant with that of the tube diameter."

Similar scales furnish dimensions for valves and other fittings, but as the question under consideration—elbows, tees and crosses—is fully covered by this scale, if the fittings are to be made of a uniform length, they need not be considered now.

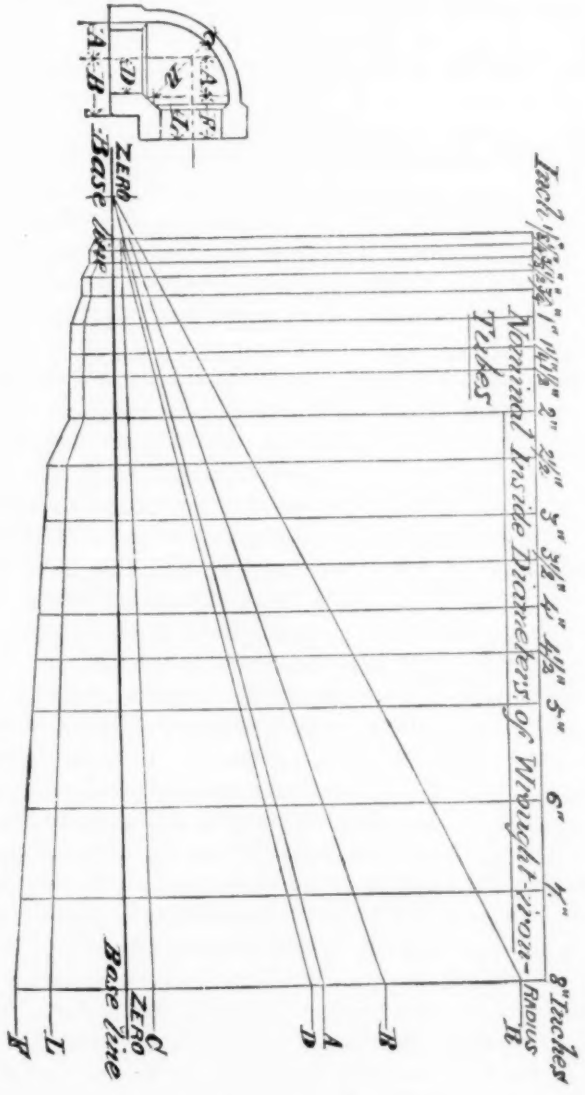
It should be noticed the distance from *F* to *A* establishes the length of the fitting from centre to end of hub—the first consideration in a standard fitting,—while from the *base line* to L establishes the length of the thread; *C* giving the thickness of the shell of the fitting, and the difference between *D* and *B* determining the thickness of the hub.

[At the meeting, full size drawings (1″, 2″, 3″, 6″ and 8″) made by this scale were exhibited.]

The questions to be determined are:—Are these sizes suitable? or, if not, what is suitable? Is the thickness *C* too great for large sizes? and Is the difference between *D* and *B* great enough for the *one-inch elbow?*—and kindred questions; and determine a new position for the ordinates.

The reason why I introduce this scale to the notice of the Society is, should a committee undertake to establish standards for fittings they will meet with both opposition and welcome from manufacturers, some of whom may be anxious that their method should be adopted, though subject to modification in dimensions. But even should a method be found in use equal to the one here described, the fact of adopting it or making it a basis of *the standard*

would be a probable cause of dissatisfaction to those in the business, and perhaps be the means of making a committee's work abortive.



This is why I select the *method* (though I must not be understood to select the dimensions unqualified) of an engineer who is

no longer among us and to whose memory and engineering skill we will raise a *tablet* more lasting than a monument by a recognition of his diagram.

If it can be made compatible, malleable-iron fittings should also agree with cast in their dimensions as to lengths, etc.; the thickness being determined by the work for which they are intended.

DISCUSSION.

Mr. Le Van.—I would like to say, in connection with this matter, that there was a committee of the Franklin Institute in existence for about four years on this subject, and the difficulty was to get the manufacturers to accede to anything, so as to establish a standard. Each one thinks that he has the best, and the result has been that we were unable to come to any conclusion, from that fact alone.

Mr. Barr.—Mr. President, I have had a great deal of experience with steam fittings, and I think others who have had occasion to use steam fittings will agree with me in this: that, for elbows especially, the fittings are too small, and that is one of the defects which I think is quite as important in considering this question as the matter of strength and the threads and the other things that were named. Now, when we come to take the embarrassment which naturally enough comes from buying fittings in an open market (and no manufacturer can afford to do that thing), he will soon have to settle down to some one set of fittings.

Several years ago I had occasion to design a series of engines which were to be built in large quantities, of which, I suppose, there are some 1,500 or 2,000 now running. They were turned out at the rate of three or four hundred a year, but not knowing where these engines had to go, the pipes and the fittings had to be gotten out entirely by drawings, the distance from the centre of the boiler to the centre of the engine being marked on the drawings. Perhaps these fittings would be cut and boxed and lie in the warehouse six months before shipment, so that in a manufactory of that kind it is very important that we know exactly what we are going to get, because we do not know where they are going. Now, for small engines using ordinary slide valves, in which the initial pressure in the cylinder would probably not be over two-thirds of that of the boiler, and in which the ordinary governors are used and the steam thereby wire-drawn, I do not know that it would make so very much difference about the size of the fittings, because

the pressure is reduced more at the governor than it is at the bend. But when we come to take automatic engines, and especially engines of large size, then the real difficulty to the manufacturer comes in. It has been my practice for some years to use the ordinary fittings up to four inches, and above that to make them. One reason why I would not use a fitting such as has been shown here, is simply because the turn is too abrupt. And another thing: I would not use a tee that would be made according to that scale reversed. It has been my practice for some time in making tees for large engines to make them like Fig. 1, using the same scale for the elbows, as shown by the dotted line. I cannot give you the dimensions, but you will readily see the difference between the two forms in a flow of steam, especially when you guarantee that you will get an initial pressure in the cylinder only one pound less than that in the boiler, with the engine one hundred feet away. That can be done very easily if you get the particular shaped bends and tees. And if there is to be any further discussion on that paper, I should like to know if there are any here who have experimented with the actual loss in pressure due to these abrupt bends.

Mr. Baldwin.—I suppose the gentleman knows that my proposition was not to accept that elbow. My elbow is simply drawn by that scale (Robert Briggs' method). I want the *method* of the scale accepted, and the committee will determine what the fitting will be by new ordinates in the diagram. The engine industry is a large one; but there are other industries that use pipe and fittings in greater quantities than the engine industry that have to be considered in this question. There are steam fitters, gas fitters, and water men that all use elbows. The elbows must fit the standard pipe, and you can make the radius as long as possible, but you must not make it so long that the fittings can be used only by the engine manufacturers. He can make special fittings, or he can bend his pipes in the fire if he wants to, and make his radius as long as he likes. But the main thing is the question of uniformity, so that all elbows and fittings of the same denomination will be alike.

Now, there are fittings in the market for any one that wishes to go into it, but what are many of them like? A man says he is selling a one-inch elbow for so much money. They connect two pipes together (after a fashion). Another sells a one-inch elbow which weighs twice as much, and has more radius, and will connect two pipes properly, but he can get no more money for it, as a gen-

eral thing, than the man that offers the light elbow. Competition may be the life of trade, but it is the death of cast-iron fittings without a standard. This has got to be taken into consideration in establishing a standard elbow or fitting. In this method of showing two elbows (Fig. 1, drawn by Mr. Barr on the blackboard), do you mean that the lengths shall be the same as proposed standard fittings?

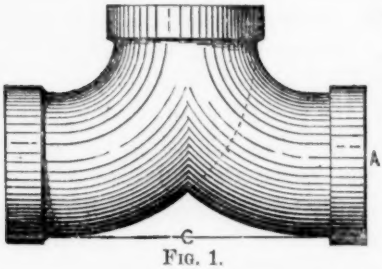


FIG. 1.

Mr. Barr.—That is intended for a very large pipe. When you get to making those tees from six to twelve or fifteen inches in diameter, you don't want to carry that line (*C*) straight across.

Mr. Baldwin.—If the flow is straight through the fitting, you do; but there are many industries to be considered, and any one may make special fittings. But length of fittings from end to centre can be the same as the trade fittings if you please, so that a man ordering them knows they are standard in this respect.

Mr. Barr.—That is not what I am talking about. I am talking about fittings specially adapted for large automatic engines, in which there must be no difference in pressure between the steam chest and that in the boiler, no matter what the length of intervening pipe may be.

Mr. Baldwin.—To meet your difficulty I would make them in the way shown in Fig. 2. The measurement from centre to end will still remain the same; but the fitting will be chambered. Again, to get nearly initial pressure in the cylinder, why not use a large supply at least as far as the throttle valve.

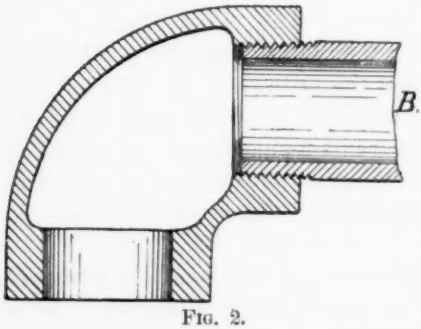


FIG. 2.

Mr. Le Van.—Why chamber it? (meaning the fitting).

Mr. Baldwin.—There is a fitting now, or there has been a fitting in the market, which was straight on the outside, like the illustration, which gave good results. Of course, you may make that by the same scale.

Mr. Le Van.—How about the expansion of volume?

Mr. Baldwin.—Oh! the volume don't expand under constant pressure.

Mr. Le Van.—You put water through an elbow like that and one that is straight through—not chambered, as shown—and see if you don't find a difference in the flow. I don't know why we should change the Morris, Tasker & Co. style of fittings, when for the past twenty years I have been using them up to a sixteen-inch diameter pipe on Corliss engines, with a difference of only two pounds between the boiler pressure and the initial pressure of the cylinder. Now, any additional length of elbow would not add to that initial pressure.

Mr. Barr.—But it will make a difference in the flow?

Mr. Le Van.—No, sir; not in the least. If I can get in a twelve or sixteen-inch pipe with only two pounds of difference between the boiler pressure and the initial pressure of the cylinder, what better can you do?

Mr. Barr.—I can do one pound better. (Applause).

Mr. Baldwin.—Gentlemen, it is not a question of changing the fittings—it is a question of uniformity.

Mr. Le Van.—If Mr. Barr's proposed tees, as illustrated on the blackboard, are to be used by having the flow of steam or water from *A* and *B* through outlet *D*, it will be a proper and desirable fitting; but, if the flow is from *A* to supply *D* and *B*, it will not be a proper fitting, as the flow will be impeded by the projection at *E* as regards the supply to *B*, as is well known to all engineers. If the fitting was made straight on the line *C*, so as to remove the projection *E* on the inside, it would make a better and more desirable fitting. I have made and used fittings of six inches diameter and upward, of this pattern, and found them to give good satisfaction.

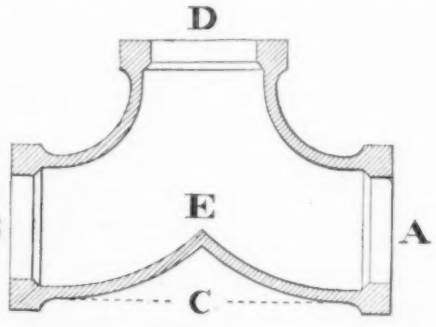


FIG. 3.

Mr. Baldwin.—I agree with Mr. LeVan. I cannot see how anything is to be gained by a hollow back *tee*, for usually two of the openings are outlets.

Mr. Le Van.—I admit that there are no two houses in the trade that make fittings exactly alike; but, if I send an order to any steam fitters in Philadelphia, and write it out, with dimensions marked from centre to centre of fittings, when I receive the pipes and put them together they will come together within a sixteenth of an inch. You cannot get these manufacturers to change their standards when they have millions of feet of pipe and fittings in actual use. When you have a good thing, why change it?

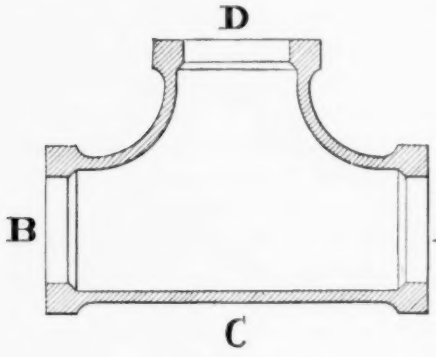


FIG. 4.

Mr. Baldwin.—For instance, if the Society can adopt the fittings of Morris, Tasker & Co. without modification or any other makers' fittings (Walworth of Boston, or Nason of New York, or Crane of Chicago), let it adopt them and try to induce the smaller dealers and others to adopt their standard. If there is a fitting with the indorsement of the Society, and a demand comes for a standard fitting, these manufacturers will find it to their interest to adopt it. The object of a standard fitting is to do away with the desire or the possibility of making light fittings, and thin and short ones.

Mr. Le Van.—You cannot control that.

Mr. Baldwin.—There was no trouble in establishing a standard in bolts and nuts. It was not a long time until the trades came to it.

Mr. Le Van.—We have not got to it yet. I bought some nuts in Philadelphia the other day, and they would not fit the bolts I had in stock, that were made within six months. (Laughter). The point I wanted to make is this: If Morris, Tasker & Co. have a standard set of fittings which is adopted by all the manufacturers in Philadelphia—and every one will admit that the interest in pipe and fittings is as large, if not larger, in the city of Philadelphia than in any other city in the country—they have a standard which is a good one. Why should we change that? All we could recommend would be that other dealers should come to that

standard. As I said before, I have been on a committee of the Franklin Institute for some three years, and I don't know how many letters we have written on this subject, but no one seems disposed to give up a standard that has answered their customers for years. All we could recommend was that all manufacturers should adopt the Morris, Tasker & Co. (Briggs') standard. I am sure no better styles and dimensions can be adopted than those of the above establishment.

The President.—It would appear to the Chair that so long as the Franklin Institute, which is a venerable and respected body, has had a committee on this subject, and has not accomplished anything in three years, that this Society can direct its attention in a more profitable direction. (Applause).

Mr. Le Van.—We would like to have some assistance from the Society. Probably its influence is greater than ours. We are a little old-fogyish, you know.

Mr. Baldwin.—The adoption by the Society of this scale of Robert Briggs as a standard will bring others up to that standard.

The President.—Of course, if the gentleman wishes, he can move the appointment of a committee later, which will bring out the views of the members of the Society on that subject, and perhaps that would be the best way to test the sense of the Society. It is not in order to make such a motion at the present time.

Mr. Walker.—I would like to ask one question relative to fittings, and taps for fittings. Is there any standard taper or size for pipe-fittings and pipe-taps? A few weeks ago we had occasion to put together some right and left hand fittings and pipes. I bought some right and left hand taps; but, unfortunately, we could not get them both of one make. We had a Pratt & Whitney right-hand tap and a Morris & Tasker left-hand tap. I found they differed a sixteenth of an inch at the large end, and almost a sixteenth at the small end. I was put in a rather embarrassing situation, having already drilled and reamed all the holes taper, supposing both taps were of the same size; but the result was, when we put the taps in the holes, the Pratt & Whitney tap would go in all right, but the holes were too large for the Morris & Tasker tap. The result was, I could not proceed with the work. I went to several dealers in Cleveland, but could not find any taps to suit either of the two taps I had. After examining about twenty taps, I found no two of same size even of the same make. My experience was the same as Mr. LeVan's with the nuts he bought to fit

bolts made by same party. Now, it does seem to me very important that some established size and taper should be given to all fittings and taps, even if the fittings do vary in their widths and proportions. I consider the proportions of a fitting secondary to a standard diameter and taper for the thread.

Mr. Henning.—I had exactly the same trouble in using fittings. I compared four different taps and dies, and I found they were all different, and so different that neither one of the taps would fit the thread cut by the other. I tried them all round, every way. The only way to make a good fit was to cut a tap in a lathe to match the die that I had of a certain maker. Neither one would fit any of the others.

Mr. Baldwin.—Mr. President, is not that an argument for standard fittings?

The President.—It is not an argument for the appointment of a committee on this subject. It is all right; but the question is, How much can we accomplish by it? It is before the Society, but the point I wish to make is this—simply as an individual, not officially—whether the influence of the Society, through its transactions and the expressed opinions of its members, will not go farther, perhaps, than the appointment of a committee. If we appoint a committee to consider this subject, it will become a sort of a charnel house for all that is said on the subject; whereas, what we say now is fresh, and will be spread broadcast, perhaps, through the country so far as it is worth going; and we can personally, perhaps, influence men. Certainly I feel as strongly as Mr. Baldwin on the subject.

Mr. Baldwin.—I want to state, for the benefit of the gentleman that asked about taps, that in Robert Briggs' last paper he will find what he wants on tap and threads pertaining to fittings. It is very complete there. It is in the Proceedings of the Institute of Civil Engineers of Great Britain, 1882–83, part I.

Mr. Grant.—Mr. President, for eight or nine years I had charge of the tap and die department of the Pratt & Whitney Company, Hartford, and when we started to make pipe taps we went to a great many different people who were making pipe taps to find what the standard taper was. The standard sizes we got at very easily, and the point of the taper was turned so that it just came through the gauges; but when we came to the taper we found it varied all the way from five-eighths of an inch to an inch to the foot. We took a set of taps that was made in Philadelphia, and

we put that into a lathe with a taper-turning attachment. We found the taps from that maker varied from a half-inch to an inch and an eighth to the foot. (Laughter.) We adopted an inch to the foot. I have not anything to do with the Company now, and have not had for two or three years. I understand that they have changed that taper to three-quarters of an inch to the foot, as being the recognized standard taper.

CRANES: A STUDY OF TYPES AND DETAILS.

BY

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In the study of any special class of machines it is often conducive to a better understanding of the subject clearly to enumerate the several types or forms in which the machine is used, and also to consider each of its more important details separately, rather than in their combination with other elements of the mechanism. It is proposed in the following pages thus to treat the subject of Cranes.

The only English text-books descriptive of cranes are Glynn's, which treats of English practice in crane building as it existed more than thirty years ago, and sundry catalogues published by English dealers in machinery as a means of advertising the products of the various builders of cranes for whom they act as selling agents. The practice represented in the former is now almost obsolete, by reason of the improvements which have been effected, and the latter consist of little but a series of pictures of various cranes, without descriptive text, and with no information as to the details of their construction.

The building of cranes has long been recognized in Europe as one of the most important subjects in the field of mechanical engineering, and cranes of many forms are there seen applied to an almost infinite variety of uses. In America, on the contrary, cranes are but little used or appreciated, in comparison, at least, with the extent of their application in European countries. It is the purpose of this paper to present to American readers a brief classification and description of the most important types of cranes, and a similarly brief study of the more important elements entering into their construction, the object of the latter inquiry being to determine, if possible, the best forms of elements to be adopted.

With a better knowledge of crane construction will surely come a better appreciation of their economy and value as labor-saving machines. In hundreds of mills and workshops heavy material is now being moved and handled by manual labor at an expense so much in excess of the cost of doing the same work far more rapidly

and conveniently by cranes, that the saving effected by the latter would yield an annual profit of from twenty to fifty per cent. upon their first cost, while in many cases this outlay would be entirely repaid by the economy of one year's use.

CLASSIFICATION OF CRANES.

A *hoist* is a machine for raising and lowering weights. A *crane* is a hoist with the added capacity for moving the load in a lateral or horizontal direction.

All cranes, therefore, are provided with hoisting mechanism, and, in addition, must be capable of moving the load in one or more horizontal directions. This second function is effected in some types of cranes by simply pushing the suspended load, in others by the operation of a distinct mechanism.

Cranes are most clearly classified by reference to their modes of transferring their loads horizontally; and, thus considered, are found to divide themselves into the following groups, viz.:

1. *Rotary*—In which the load is revolved around a fixed centre, such as a mast or column.

2. *Rectilinear*—In which the load is moved in straight lines, in one or more directions.

Both types of cranes are subdivided into two general classes as to their movements, viz.:

(*A.*) *Fixed*—When their supporting members are fixed in some permanent location.

(*B.*) *Movable*—When the crane as a whole can be moved about.

And into four other general classes as to their source of motive power, viz.:

(*a.*) *Hand*—When the motions, either vertical or horizontal, are effected by manual power.

(*b.*) *Power*—When the motions are effected by power derived from line shafting driven by a stationary engine or other fixed motor.

(*c.*) *Steam*—When the motive power is derived from a steam engine attached directly to the crane itself and moving with it.

(*d.*) *Hydraulic*—When the motive power consists of hydraulic pressure obtained from a pump or accumulator, and carried to the crane by pipes.

A further distinction is covered by the term locomotive, which

is applied to cranes (usually of the rotary type) which are capable of propelling themselves upon a roadway or track.

Rotary cranes comprise the following principal types, viz.:

1. *Swing Cranes*—In which the central mast is pivoted to the floor and roof of the building, and the load is suspended from a block fixed at the outer end of an arm projecting horizontally from the mast, the only horizontal motion being one of rotation.

2. *Jib Cranes*—In which the central mast is pivoted to the floor and roof of the building, and the load is suspended from a trolley traveling in and out upon an arm or jib projecting laterally from the mast.

3. *Column Cranes*—Which consist of a jib crane constructed to revolve around or upon a fixed column forming the support of a building or floor.

4. *Pillar Cranes*—In which the central column or pillar is entirely supported by a heavy foundation built at its base, and the load is suspended from a boom projecting from the pillar and revolving with it or around it.

5. *Derrick Cranes*—Which consist of a jib crane for yard use, the upper end or pivot of the mast being held in position by guy-rods or stays, instead of by attachment to a roof or ceiling.

6. *Walking Cranes*—Which consist of a pillar or jib crane mounted on wheels, and arranged to travel by power or by hand upon one or more rails.

7. *Locomotive Cranes*—Which consist of a pillar crane mounted on wheels, and provided with a steam engine and boiler, the power of which is available for operating the crane and for propelling it upon its tracks.

Rectilinear Cranes comprise the following principal types:—

1. *Bridge Cranes*—In which a fixed bridge spans an opening, and the load is suspended from a truck or trolley capable of moving across the bridge.

2. *Tram Cranes*—In which a truck or short bridge, from which the load is suspended, is arranged to travel longitudinally upon a pair of overhead rails, but is without capacity for transverse motion.

3. *Traveling Cranes*—In which a rectangular space is provided with overhead tracks upon two of its opposite sides, and is spanned by a bridge arranged to travel longitudinally upon these tracks, the load being suspended from a truck or trolley capable of moving transversely across the bridge, so that the load may be moved to or from any point within the entire rectangle.

4. *Gantries*—In which an overhead bridge is supported at each end by a frame, or trestle, extending downward, and having wheels in its base to permit of travel upon two longitudinal tracks laid upon the ground, so that the entire structure can move endwise upon the latter, and the load, which is suspended from a truck or trolley on the bridge, can be moved transversely across the bridge.

5. *Rotary Bridge Cranes*—Which combine a rotary with a rectilinear movement, and consist of a bridge having one end pivoted to a central pier or post, while the other or outer end travels on a circular overhead track, or is supported by a gantry frame traveling upon a circular track upon the ground, the load being suspended from a truck or trolley traveling transversely across the bridge.

The above nomenclature will be adhered to in the following descriptions of crane construction.

CRANE DETAILS.

HOISTING GEAR.

The most important factor in the economy and convenience of a crane is the mechanism by which the load is lifted and lowered, as it must necessarily come into action every time the crane is used.

In all applications of power, from whatever source derived, it must be remembered that the gearing of a machine can only modify the power applied in one of two ways, viz.:

(1.) By reducing its velocity, and proportionately increasing its force or "pull."

(2.) By increasing the velocity, and proportionately decreasing the intensity of the power transmitted.

Under no circumstances, unless the motive force is increased, can power be gained except by a sacrifice in speed, or can speed be increased except by a sacrifice in power. If either or both must be increased without diminishing the other, it can only be accomplished by supplying more motive power.

The function of gearing, then, is to change the force or direction of the power applied. If it is well designed and constructed, this may be done with only a small loss from friction; while, if badly made, the gearing may absorb much power in wasteful friction of its moving parts.

In machinery for hoisting, the "purchase," or conversion of

velocity into lifting power, is usually effected partly by a multiplication of the ropes or chains of the tackle through which the load is suspended, and partly by gearing within the machine, which latter thus becomes an important feature in crane work. The gearing ordinarily used for this purpose consists either of spur wheels and pinions, or of worm wheels and worms, or both combined, and the smoothness and economy of power of the machine depend largely upon the manner in which the gearing is made.

A second feature of prime importance in the hoisting gear of a crane is the mode of sustaining the load, and guarding against its "running down" when the application of the motive power is discontinued. This has heretofore been accomplished, in machines having spur gearing, by a ratchet wheel, the pawl of which has to be entirely disengaged to permit lowering to occur, or by a brake which, when on, prevents all motion of the machine, and which requires to be held or thrown off, both in hoisting and lowering. In machines having worm gearing, the end is attained by a construction of their worm wheels such that the friction between the worm and the wheel is sufficient to prevent the backward rotation of the worm under the pressure of the teeth of the worm wheel caused by the load, the resistance thus generated sufficing to prevent the running down of the load.

The worm-wheel system is usually safe against accidents, but is not economical of power if the worm gears are proportioned, as above explained, to hold the load suspended without running backward when the application of power ceases, as is usually the case. The spur-wheel system, on the other hand, is a constant and inevitable source of great danger, both to the load and to the operator. With the least carelessness in lowering, the load begins to descend with great velocity, and the mechanism is driven backward with corresponding speed and violence. If not checked, the load then practically falls as if unsupported. If too suddenly checked, violent strain is thrown upon the entire frame of the crane and on its gearing, which latter is thus liable to damage, and even to "stripping" or fracture, in which event the load falls. Where spur-geared cranes are operated by hand this "running down" of the load involves a reversing or "flying back" of the cranks, which then frequently strike the men before they can escape beyond their reach. Accidents of this kind, resulting in injury to limbs, and even to life, are constantly happening with common cranes, and are reported almost daily in the newspapers.

It is possible, however, so to proportion worm-gearing as to place it almost, if not wholly, upon a parity with spur-gearing in regard to economy of power transmitted, and, by the use of cut worm wheels, driven by turned worms or pinions (the teeth of the wheel being formed by means of a chasing hob or cutter), so to construct worm-gearing that it becomes the best and most convenient form of gearing for use in crane mechanism. It is found that gearing thus made will not automatically support the load, and that the latter, if left suspended, will drive the worm-gearing backward, but in this case the descent of the load is quite slow, and no perceptible acceleration takes place, so that the worm gears thus act as a governor to control the load. By the application of a small brake to the worm-shaft this tendency is counteracted, and, by connecting this brake with the levers which control the motions of the mechanism, the brake is easily made automatic, and thus securely holds the load whenever the crane mechanism is at rest.

In all cranes, except those of small size, provision should be made for one or more changes of speed in hoisting and lowering, so that the speed may be varied according to the load and the nature of the work to be done. Cranes operated by power *may* be so constructed that the maximum load can be lifted at the quickest speed; but they are usually so proportioned that this can be done only at a slow speed. By this plan much economy of gearing, space and cost is effected, and the practical efficiency of the crane for all ordinary uses is not impaired. The most perfect construction is one that permits a change of speeds to be made whether the hoisting gear is in motion or at rest, and which sustains the load automatically while a change of speed is being made.

The hoisting gear of a crane should therefore attain the following results, viz.:

(1) Such changes in direction and velocity of the power applied as will give the desired motions to the load.

(2) The accomplishment of this with a minimum loss of power through friction.

(3) The safety, both of the operator and the load, under all conditions; to insure which the load must be always self-sustained and incapable of "running down."

(4) Capacity for changes of speed and for convenient transition from one of these to another at will, whether the gearing is in motion or at rest, and for the automatic support of the load during the act of changing speeds.

TRAVERSE GEAR.

In this, as in the hoisting gear, good design and construction are essential to economy of power, and frequently to safety against accidents.

In some types of rotary cranes no traverse mechanism exists, except an arrangement of parts which provides for the rotation of the crane. In others, such as jib and derrick cranes, provision must also be made for moving the truck or trolley horizontally on the jib, and the same provision is required for moving the trolley of bridge and traveling cranes transversely on the bridge. In all such cases a separate mechanism, distinct from the hoisting gear, has heretofore been employed, and is still sometimes desirable or convenient. When employed, its parts should be as few and simple as possible, and it should be so far independent of the hoisting gear as to permit either to be used at any time separately or conjointly. In power cranes provision should be made for accelerating the speed of the trolley-travel whenever the nature of the work admits of it. The best possible result is attained when travel of the trolley is effected without varying the vertical position of the load, and without causing useless movement of the hoisting chain or rope over the sheaves through which it supports the load, which movement would involve much additional friction, and cause rapid wear of the chain or rope.

In traveling cranes a point of great importance is the parallelism of the bridge travel with the longitudinal tracks. Any defect here results in increased resistance to traction, and any considerable error might cause derailment. In traveling cranes, as heretofore built, the use of flanged wheels has been relied upon to prevent derailment, and the propulsion of the bridge has been effected by a transverse shaft extending the whole length of the bridge, and connected by gearing with the truck wheels supporting each end of the bridge, so that, by revolving the shaft, the truck wheels would be rotated, and the bridge be thereby propelled, provided the adhesion between the wheels and the rails was sufficient. In some instances, where the adhesion has not been sufficient to prevent slipping, a cast-iron rack has been laid adjacent to the longitudinal tracks, and extending their whole length, and pinions, gearing into this rack, attached to the axles of the truck wheels, so that propulsion is effected independently of the adhesion of the truck wheels to the track. If the load were always central on the bridge, and

the motive power always applied to this shaft at the centre of its length, this plan would answer well, although it is somewhat clumsy; but in practice the load is constantly varying in position, and the motive power is applied at one end of the long transverse shaft, so that torsion of the shaft induces a considerable variation in the travel of the opposite ends of the bridge. This error is a constantly varying one, according to the portion of the load resting upon each truck, as determined by the position of the trolley, the load being never equally distributed between the two trucks except when it is exactly in the centre. It follows, therefore, that this system of bridge travel, although operative, is radically defective, and that its use involves a constant loss of power by needless friction, and entails a proportionate amount of wear and tear of rails, wheels, and driving gear.

A better and more simple method of bridge propulsion has lately been introduced, by means of which the longitudinal motions of the bridge are effected by *pulling* each of its ends, simultaneously and at equal speed, in the desired direction. For this purpose light wire cables are used which, by a very simple and ingenious arrangement of guide-sheaves, are made to act as a "squaring device" to hold the bridge at all times perpendicular, or square, to the tracks upon which it travels. By this system the friction of traction is reduced to a minimum, and the danger of derailment from unequal travel of the opposite ends of the bridge entirely obviated.

From the above facts it becomes evident that a perfect system of bridge propulsion must hold the bridge always absolutely square with its tracks, and must propel the opposite ends of the bridge in the same direction, at the same time, and at the same speed, however unequally the load may be distributed. It is desirable also that, in large cranes at least, provision be made for starting the bridge slowly from a state of rest, and then increasing the speed, and also for varying the speed while the bridge is in motion.

CHAINS *versus* ROPES, AND CHAIN WHEELS *versus* DRUMS.

In almost every type of crane the load is primarily carried upon a flexible cord of some kind. This usually consists of rope, either hemp or wire, or of chain. Each of these has distinctive merits and objections.

Ropes have the advantage of being formed of many parts or fibers, so that no splicing or welding is necessary in their manufacture; and they thus have an assured and practically uniform strength throughout their length.

Chains, on the contrary, consist of a series of independent links, each of which is formed from a straight bar, and welded, so that a single imperfect weld injures the whole, the strength of a chain being obviously limited by the strength of its weakest link. By care and good workmanship, however, this danger can be avoided, in which case the chain becomes as safe as the rope, and much more durable.

Where a rope is used, the hoisting gear must necessarily include a drum or barrel upon which the rope is wound up when hoisting takes place. Chain may also be thus wound up on a barrel, and this has heretofore been the common practice when chains have been employed in crane construction, and a prominent feature in cranes of large capacity has usually been a proportionately large "winding barrel" to receive the chain. A chain, however, admits of another mode of construction, which consists in substituting for the wide barrel or drum a pocketed "chain wheel," consisting of a narrow wheel or sheave, of a width only slightly greater than that of the chain, and having formed upon its periphery a series of indentations, or "pockets," exactly corresponding in size and shape with the links of the chain, so that the chain and the pockets fit together accurately, and slipping of the chain upon the chain wheel becomes impossible. It thus follows that rotation of the chain wheel causes positive motion of the chain at a speed equal to the circumferential velocity of the wheel, in a manner precisely similar to the motion of a rack driven by a pinion, or of one spur wheel driven by another.

To be used in this way, it is necessary that the chain should have a constant and uniform "pitch," that is, that every link should be exactly alike, so that the distance from link to link shall be always the same (just as in spur gearing the spacing, or pitch, of the teeth must be uniform), and also that the pitch or spacing of the pockets of the chain wheel corresponds accurately with the pitch of the chain. If this be done, and if the chain have a cross section of such area that, when carrying the full load, it is not strained to its elastic limit, or to a degree which will cause any permanent elongation of its links, then a chain may be thus used, in engagement with a pocketed chain wheel, as well and as safely as on a barrel. Indeed, a properly shaped wheel of this kind is much easier on the

chain than a winding barrel or drum, for the reason that the latter has a cylindrical surface, while the bearing face of the former is not cylindrical but polygonal, the bed or bottom of each pocket being tangential to the radius at its centre, and so presenting a flat surface for the parallel sides of each alternate link to bear upon. When the chain is wrapped upon a cylindrical barrel, on the other hand, the straight sides of every alternate link, being tangential to the surface of the barrel, can each touch it at one point only, the link being unsupported throughout the rest of its length, and the tendency of the strain induced by the load is to bend each of these links to the contour of the barrel. This effect may be easily seen in any chain which has been wrapped, under severe strain, upon a cylindrical barrel, unless the diameter of the barrel be very large. The spiral grooving of a barrel does not remedy this fault, although it affords a much better bearing for the chain than a plain cylinder; which latter is only permissible for small chains and light loads.

For heavy cranes hemp ropes are rarely used owing to the size and multiplicity of parts required, and to their rapid wear. They are also inadmissible where liable to be exposed to much heat as, for instance, in a foundry. Wire ropes are more available, and are often employed, but these also wear rapidly, unless the sheaves and barrels around which they pass are of large diameter, while this requirement, if met, reduces the effective height of hoist and necessitates more parts or gearing to obtain the necessary purchase, and augments the bulkiness of the machine. Either material involves resort to a large winding barrel or drum.

The usual and best device for large cranes is well made chain, and this, when used with pocketed chain wheels and sheaves, gives the best and most satisfactory results, and leaves nothing to be desired. The adoption of this plan dispenses with winding barrels, preserves the shape, and therefore the durability, of the links of the chain, and in every way simplifies and compacts the mechanism.

The relative merits of the several systems may now be summed up as follows:

(1) *As to the Sustaining Cord.*

emp Ropes.—Admissible only for small cranes not in frequent use and not exposed to the weather or to heat.

Wire Ropes.—Available under any ordinary conditions, but

involving a winding barrel of large diameter and large sheaves; not economical of space.

Chains.—Possessing, if well made, all advantages and the greatest durability: *common chain*, requiring a winding drum, but permitting it and the sheaves to be of smaller diameter than with wire rope; *pitch chain*, dispensing with a drum and admitting of the use of a narrow chain wheel.

(2) *As to the Winding Device for Hauling in and Paying Out the Rope or Chain.*

Winding Drums or Barrels.—These must have a diameter and length such as will enable them to receive the whole length of rope or chain to be hauled in by winding it upon their surface in one coil, without overlapping. In large cranes the load is usually carried upon four, six, or even eight parts of rope or chain, so that the length to be wound up amounts to four, six, or eight times the effective hoist, and the dimensions of the barrel thus become very large. Moreover, this barrel must either be caused to travel longitudinally on its shaft, so that the rope or chain as it leads off shall be always in the centre of the crane and hoisting mechanism (which method of construction involves serious complication and greatly widens the space occupied by the gearing), or the rope or chain, as it uncoils, be permitted to vary in position from one end to the other of the barrel, in which case it is nearly always out of centre, thus inducing objectionable lateral strains and causing greater friction and wear.

Chain Wheels, with Pockets.—These require a width only slightly greater than a single part of the chain, and a diameter merely sufficient to give the proper engagement with it, so that both dimensions become much smaller than in a winding barrel, and the total space occupied is but a small fraction of that required for the latter device. The *chain wheel* is fixed in direct line with the chain, and all lateral strains are avoided, while the flat bearings afforded for the chain by the pockets preserve the shape of the links and protect them from bending strains. The slack chain, after passing over the wheel, falls into a proper receptacle below.

From this analysis of the facts is deduced the proposition that chains, if well made, constitute the best form of flexible cord for sustaining the load in a crane, and that a well constructed *chain wheel* (as contradistinguished from a winding barrel) is the best

form of device for hauling in and paying out the chain; and, therefore, that the best method of crane construction involves the use of these two elements.

TROLLEYS AND TRUCKS.

The trolley of a crane is the movable carriage from which the load is immediately suspended and by which longitudinal motion of the load upon the jib, or the bridge of a crane, is effected. The term truck is usually restricted to the wheeled carriage used to support each end of the bridge of a traveling crane, or the corresponding part of rectilinear cranes of all kinds. Rectilinear cranes require usually at least one trolley, and one or more trucks. Rotary cranes require usually a trolley only.

The whole load of a crane is hung primarily upon the trolley, and where trucks are used, is transferred in full to them, together with the weight of the crane itself. It is desirable, therefore, that these parts should not only possess ample strength to resist the strains they may be subjected to, but also that they be so arranged that any yielding or breakage of their parts will not allow the load to fall to the ground, but only permit it to descend until the supporting beam rests on the rails upon which the trolley or truck is to travel. For this reason the construction should be such that the ends of the bridge, in traveling and similar cranes, overlap the longitudinal tracks, and the axles or housings of the trolley, in cranes of all kinds, overlap the rails upon which it runs. It is further desirable that the vertical distance between these overlapping parts and the rails be as small as possible, so that, in the event of any break occurring, the distance through which these parts pass before being arrested is so small that no serious shock can ensue. With careful designing this distance can be reduced to merely the necessary clearance of the parts, which need not exceed more than one inch or less.

A natural preference exists for wrought iron rather than cast-iron as the material from which to construct the moving parts of a crane; and, unquestionably, it is always best to use wrought iron for parts that are to be exposed to tension under heavy loads. Cast-iron, however, is the better material for those parts that are subject to compression, and by skillful designing it is usually possible so to arrange the parts of trolleys and trucks as to use cast-iron wherever stiffness or resistance to compression is required, while still employing wrought iron for the parts under tension. In this way the

greatest economy is attained, and not unfrequently a better result secured than by the use of either material alone.

The wheels both of trolleys and trucks should be true cylindrically, should be double-flanged, and, by preference, should have chilled treads. If wheels of small diameter are used, in order to economize height, they should be provided with anti-friction bushings, to counteract the increased resistance to traction caused by their small diameter. The wheel-base, or distance from centre to centre of the adjacent wheels, should be as large as possible, in order to avoid cramping between the rails, and to facilitate the easy motion of the carriage upon its track. In large traveling cranes it is desirable that the axles of the truck wheels be supported in spherical bearings, so that the wheels may adjust themselves to any yielding of the track which may result from the passage of heavy loads, and thus all unnecessary straining of the parts of the truck be avoided.

FRAMES AND GIRDERS.

In the early building of cranes, timber was chiefly used in the construction of their frame-work, and is still much employed in this country. Improvements in the manufacture of structural irons, and the large variety of shapes now obtainable, have, however, greatly altered the relative cost of construction in timber and iron, and made it possible to employ iron much more largely than formerly.

Experience in the practical designing and building of cranes of many types has convinced the writer that, by the proper use of materials, crane construction in iron costs, in most cases, little, if any more than in wood. For example: The frame of an ordinary jib crane consists of three principal members—the mast, the jib, and the brace. If of iron, each of these consists of a single piece or bar, or, in larger cranes, of two parallel pieces, and the union of these several members at their intersections is accomplished simply and very economically. If timber be used, on the other hand, more or less trussing is required, except for small cranes; and many bolts, washers and castings are necessary to provide for the proper bearing of one part upon the other and to securely fasten the several parts together. The iron frame, when once properly put together, is practically imperishable. If properly painted it will not deteriorate, nor is it affected by exposure to the weather or by extremes of heat and cold. A timber frame, on the contrary, is liable to

decay, which is hastened by exposure to the weather, and it is unfavorably affected by heat. More or less shrinkage of the timber always occurs, thereby relaxing the engagement of the several parts, and disturbing the relations of the bearings which receive the strains caused by the load. The result of these changes in a timber frame is to permit more or less working of the parts one upon the other. This tends to augment the trouble from which it arises, and as a result the safety of the crane is lessened and its durability continually impaired.

So also in the bridges of traveling cranes. If the span be great, construction in timber involves much splicing, and this in turn necessitates unnecessary material in many places. The trussing and bolting requires a considerable amount of iron-work, and usually necessitates a deeper girder than is required in iron, thus lessening the available head-room beneath the crane. It is believed that an accurate comparison of the relative costs of crane frames or girders built in wood and in iron, if proportioned with an equal factor of safety throughout, would show little if any economy of first cost in favor of wood.

The availability of iron for structures of this kind has been greatly increased by the ability of the mills to produce extreme lengths when required. No difficulty is now experienced in this country in obtaining the heaviest channel and I-beams in lengths of 50 feet or more, and the largest angle irons are also obtainable in single lengths of 80 or 90 feet. It thus becomes possible to form each of the principal members of cranes of a single continuous iron, the advantages of which are too obvious to need description.

It will be conceded that iron frames and girders are much to be preferred for every reason, with the single exception of possible economy of first cost. Taking into account, however, all of the conditions and considerations above mentioned, it is believed that the difference in first cost is so slight—in many cases not appreciable—that the frames and girders of cranes of all, except perhaps the smaller kinds, should now be built entirely of iron.

In conclusion, it may be hoped that the foregoing analysis will conduce to a clearer understanding of cranes, both as regards their various forms or types, and the more important details of their construction. The tendency of the day in all directions is toward the specializing of products; that is, the concentration of the abilities and resources of individual establishments upon the develop-

ment of certain distinct or special products. Consumers are the ones most benefited by this condition of things, since it enables them to procure products of higher quality and ultimately at a lessened cost. Where such specialists exist, the best result is usually attained by submitting to them a clear statement of the work to be done and of the surrounding conditions, and by accepting the advice thus obtained as to the type or form of machine best adapted to meet the special requirements of the case.

DISCUSSION.

Thos. R. Morgan, Sr.—The discussion in this admirable paper on "Cranes" is so extensive, that I can hardly in so short a time, discuss the specialty of traveling cranes, as they are the most important and the most complex of all cranes. It would take more time and space than I have at my disposal to do the subject justice, and to get at the best facts. The paper only came into my hands last night, and I must say has been well gotten up, with great care and has a great many facts and experiences, on one side of the question. All questions, especially of this character, however, have more than one side, and what we all need is to get at the best if possible. I desire to call your attention to some experiences and practice which I have had with cranes. The investigations I have made have been of as exhaustive a character, I think, as it has been possible for me to make, both in literature and practice, as I have made the question a study, with a desire to get at the best possible results. There are a few points of importance where I differ somewhat with Mr. Towne, which I would like to call your attention to:

(I.) *On the subject of spur and worm gearing, and with regard to the danger of using one over the other.* With the comparative practice of worm and cog gearing, I have had considerable experience, both on heavy and light work, and I must say that my experience with worm and tangent wheel gearing, has been of a very unfavorable character. I have never believed that worm and tangent wheels are a good gearing for anything that has heavy work to do. For continuous motion of a feed character or light work, I have found the worm gear best. But, for heavy, hard work, subject to the control of common labor, and to dusty conditions, to all of which cranes are exposed, I would consider them the reverse of best. My experience of the practical working fully agrees with

the theory of the operations of the teeth of worm and tangent wheels. But both theory and experience are very much against them as a reliable power, unless the teeth are fully protected from contact with each other by a closed box filled with good lubricant. Should the lubricant fail, it must be evident that if the teeth of the worm and wheel come in contact, they would soon grind each other to powder. The top or outer periphery of the tooth travels much faster than the inner periphery, or bottom of tooth of the worm, and the teeth of the tangent wheel, which is operated by the worm, run *vice versa* to the teeth of worm. In other words, the outer periphery of the teeth of the tangent wheel would travel the fastest, on the point, in contact with that part of the tooth of the worm which travels slowest. At the bottom part of teeth of tangent wheel, where its teeth travel slowest, the worm tooth travels fastest, so that it must be evident that continuously varying speeds of revolution are going on from top to bottom of the teeth of the worm, operating against the varying speeds of circumferential travel of the teeth of tangent wheel, so opposed to the natural conditions as to cause a grinding instead of a rolling motion. Another source of great trouble with the worm and tangent wheels, even with best frictionless precautions, is the face friction on end of worm, in its thrusts. This has been a cause of great annoyance under hard work. Practical men of long experience know this to be the fact, but with the ordinary straight cog gearing well made, all such conditions specified about the worm and tangent wheel are avoided, and a natural rolling of the teeth of the wheels on each other without any lubricant is the result. Such wheels under fair conditions and good designs, will last a life-time even in foundries, and rolling mills, where dust is continually flying around. Hence I contend that for "traveling crane" purposes, for simple, permanent conditions, and economy of power consumed, plain cog gear wheels are best adapted for the purpose.

(II.) *Parallelism.*—I have had experience with traveling cranes for some thirty-two years; worked with them practically, and built some of them; and practice is a very good field to get facts from. About twenty-five years ago a crane was built at the Blaenavon Iron Works, Wales, to place over the roll-turning shop. I was there at the time. It had a rack gearing alongside of the track to control the "parallelism" of longitudinal travel of bridge, which was found not to be necessary. We find to-day the best makers in

the world have done away with the rack, and depend on the traction of truck wheels alone. With regard to the danger to the parallelism of traveling cranes, when operated through a line of shafting across, I don't think that there is any. I have never known any to exist. There may be such a case through poor construction and work. I have never heard or seen the report of a traveling crane falling down in my life, and the practice of leading makers of long and large experience refutes that idea. With regard to the two flanges on track wheels, I think that the double flanges are simply made as a safeguard, so that if there *should* anything happen, the crane would wedge itself, and could not fall down. Then there are other methods of protection, if they were necessary, such as placing horizontal guide wheels alongside of the track, so that there could be no possibility of danger on that point. But the practice of many leading makers in Europe, for long periods, prove that even to be unnecessary.

(III.) *The square shaft as a motive power, versus the wire rope.*— I contend that the motive power through a square shaft along the shop, where made properly, is simple and permanent in character, and is far less objectionable than the driving through wire rope at high speed, and with the intervention of worm wheels to obtain power. The worm becomes generally necessary to reduce the speed and gain power. With such conditions as are imposed by the high-speeded wire rope, worms, sheaves and ropes have to be renewed at intervals; sheaves must be kept in order, and wear and tear of worms and small gears must be proportionately great. The life of working details is not of as long duration as it might be. Another great objection to the wire rope is the sagging of rope, whenever the lifting of loads takes place. The rope is kept in tension by balance weights, which forms another objectionable feature in work-shops. As a manufacturer of cranes, I have made the most careful investigations into the best modern practice, and taken the views of many men who have had large modern experience and long practice in that field, and for the benefit of the members I beg leave to lay before you my experience and practice resultant therefrom. At our works we have to handle a large amount of difficult and heavy pieces of machinery, and our labor force was becoming burdensome, slow, and destructive in many ways. Being driven with other work, we could not make our own crane, and we decided to order a traveling crane, of twenty tons capacity, from Appleby Bros. of London, who, no doubt, have had more experience in that

line than any other makers. We stated fully to them that we wanted their best modern traveling crane. They advised that our crane be driven by a square shaft, supported by tumbler bearings, as the best. The shaft we were to make ourselves. It was to be made in a number of ordinary lengths, spliced, and riveted in the best manner. In their experience they had found it best not to advise that these shafts should be more than three hundred feet long on that system of driving to do such work. Soon after receiving their drawing, one of the most experienced engineers of England, and now one of its leading builders of machinery, paid us a visit. He is also a large manufacturer of cranes. I asked him why the Applebys did not advise a shaft longer than three hundred feet. He said they gave way at the joints. This confirmed my views, and led me to determine to make the main shaft of our crane one hundred feet long, in one piece of three-inch square iron. This has been in operation for about one year, and I am convinced that it will stand the hard work of a life-time, without any renewal, as far as the shaft itself is concerned.

TRAVELING CRANES IN GENERAL.

In our Appleby crane there are a number of excellent practical features. Important prime features will bear great improvements, and, I am sorry to say, the workmanship throughout bears no comparison with our practice in this country, and has been a source of great disappointment to us. But in its practical operations of doing the work, barring the terrible noise the crane makes, owing to minor defects and bad work, I considered our crane, three months ago, the best practical working crane of its kind that I have yet seen in all my investigations, of many and most modern of various makers' cranes. After carefully watching our own crane in operation I prepared a new design to improve all defective parts, simplifying and quickening the many changes, and at the same time aiming to make a crane as nearly noiseless as possible, as well as to place the crane under the control of a common laborer, or boy, who can read a few simple words placed over each handle, operating the changes of motion, such as "Quick," "Slow," "Up," "Down," "In" "Out," Brake. The latter is controlled by the foot, and the load in lowering is always, if desired, controlled by the foot. The traveling motions, both longitudinal and crosswise of bridge and carriage, are controlled independently of the operator. Stop or disen-

gaging motions are placed at each end of the travel. All these conditions, we have been enabled fully to carry out with detailed success, to our full satisfaction and to that of our customers, and some of the leading and most experienced manufacturers of locomotive and stationary engines. The Dickson Manufacturing Company, Scranton, Pa., have a crane of fifty feet span, and of twenty-five ton capacity. The shaft is two hundred feet long in one piece. We have been signally aided in our efforts to improve a most important defect in the Appleby crane by substituting the Frisbie patent friction clutch, which enables us instantly to stop and to start every operation of the crane, and at the same time to reduce the speed of first driving shaft by one-third. This results in reducing wear, and in making the crane practically noiseless, giving immediate instead of slow changes. We have a number more of larger capacity of same kind now building. We cordially invite members interested in this subject to call and see the Appleby crane, and we have no doubt that the Dickson Manufacturing Company will welcome any member to see theirs. Examine, also, into the practice of others of modern make and different type. Judge and reason for yourselves as between the two systems, as shown in their practice. This is the way we did in selecting our present system, to which we are only tied where we believe it best. We believe that any member who will carefully examine in detail the cranes on this system, as strengthened and improved, with ample power of simple cog gearing controlled by stop motions, and calculating Frisbie's frictional adjustments, will find, instead of danger anywhere, that the controlling features throughout are simple, permanent and economical. As to the improved traveling crane as now built, it is embarrassing for a member who is a manufacturer to discuss questions in his line of business. But as I consider that the Society of Mechanical Engineers desire practical facts, and that it should be supposed that a manufacturer in a line of business should have experience and knowledge in that line, and is desired in discussion to give his experience and views freely, I have done so, in this spirit only, leaving my practice to the investigation of the members, for them to ascertain whether they will bear me out or not.

Mr. Walker.—In Mr. Towne's paper of this morning, I notice some remarks comparing the regular round drum to a pocketed chain wheel. I had better read, perhaps, a few lines that will preface what I want to say:

"Indeed, a properly shaped wheel of this kind is much easier on the chain than a winding barrel or drum, for the reason that the latter has a cylindrical surface, while the bearing face of the former is not cylindrical, but polygonal; the bed or bottom of each pocket being tangential to the radius at its centre, and so presenting a flat surface for the parallel sides of each alternate link to bear upon. When the chain is wrapped upon a cylindrical barrel, on the other hand, the straight sides of every alternate link, being tangential to the surface of the barrel, can each touch it at one point only, the link being unsupported throughout the rest of its length, and the tendency of the strain induced by the load is to bend each of these links to the contour of the barrel."

This is the point I want to explain. The pocketed chain wheel described is very popular; and justly so. It saves the chain from being damaged in the links, but it cannot be applied advantageously on drums. The fact brought out in Mr. Towne's paper is that links will be destroyed or broken by lying flatwise on the barrel. The point I want to bring out is that flat links should not bear on the drum. The vertical link working in the groove should touch on the bottom of groove only; a chain passing over a wheel or drum should pass over with the alternate links at right angles, the horizontal links never touching the barrel. I think this is worthy of notice, and will meet the objection made in Mr. Towne's paper to the destruction of chains on cylindrical drums or wheels. Some time ago our Government of this country investigated this very question as to chains running around cylindrical drums. I understand, after investigation, it was found that their chains were breaking from the ill-effect produced by the flat link bearing on the drums. Afterward the drums were made so that the vertical links would always bear on the bottom of the grooves.

Mr. Collins.—I have made a little sketch on the blackboard, showing a method by which two drums can be used to avoid winding the chain on a spiral drum. The grooves for the chain are made so that the groove on one drum comes opposite the high place on the other drum. The chain from this groove passes over on that one and back on this groove, and has the effect of a spiral drum, and yet the chain can always be in the same place, the chain always coming on one drum in the same groove, and always passing off the other drum at same place. There is one objection—that the binding force of the chain around the two drums

has a destructive effect upon the bearings; but to obviate that, place upon the drum shafts friction wheels the same diameter as the drums, and upon the driving shaft, which is between the drums, put a roller bearing on these wheels, and you have the whole thing. This kind of a drum will work, and work well, and it never changes the position of the chain. It has all the advantages of a spiral drum without its disadvantages.

Mr. Oberlin Smith.—Mr. President and Gentlemen: There was a point touched on by Mr. Morgan this morning, among other things, that I think of a great deal of importance, and that was what we may call "hoisting nomenclature." It is the custom in a great many places where hoisting machinery is used to give the word of command in such terms as "Hoist her down," "Now, let her go," "Let her run a little," "There, now, that will do," "Run her out a little," "Run her back," "Whoa! there," and all such terms, sometimes in a very indistinct voice. This is, undoubtedly, a source of danger, especially with power cranes, which move quickly, and there should be provided near every hoisting machine a card stating what words of command are to be given, in all cases where words can be heard at all. There are cases where there is so much noise that a code of visual signals should be adopted, but in most cases words can be heard if they are properly spoken; and, of course, they should be sharp and crisp, perfectly plain and definite, and the same word should always mean the same thing. I know in one of the best shops in Philadelphia some years ago the practice was to say anything at all. A very frequent expression was, "Hyst her away now." My practice is to have a code of words which must be strictly adhered to—simply "Up," "Down," "In," "Out," "East," "West" ("North," "South," if the crane happens to so stand), and "Stop." Just these seven words will manage an ordinary crane. Of course, where there are more motions other words are necessary, but they can all be just as short as these; and if the workmen are allowed to use no others, and are trained in speaking distinctly and loudly, it may in some cases save serious accidents.

Mr. Capen.—I should like to say, in connection with the subject just referred to by the gentleman, that it has been the practice in instructing the operators of cranes manufactured by the Yale & Towne Manufacturing Company, to take their directions from motions of the foreman or whoever may have charge of the job. There are no words used whatever. He makes his motions, up or down,

as the case may be, with the hand, and a quick upward motion of the hands stops all motions. I find that to work much better than any shouting.

In regard to the discussion, I am very sorry that Mr. Towne is not here to take his side of the question. I hardly feel capable of it. I hope that you will give him an opportunity to reply in the minutes. I should like also to say that in preparing his paper he was very careful indeed to avoid all business discussions. I know he devoted a good deal of pains to writing a treatise as well as possible without bringing the matter of business into it.

The President.—I believe it is a rule of the Society that members have the privilege of so correcting the stenographic report that they can say what they intended to say instead of what the reporters sometimes make out they said. A great many men can think better sitting in a chair with a pen in their hand than they can on their feet. So that I think the rule of the Society has been for them to write out their remarks made in discussion. Is there any further discussion?

Mr. Morgan.—Mr. President: I would like to say one word. I think that in societies of this character a great deal of liberality should be allowed, and, I believe, is generally allowed; that when any person shall speak on a subject pertaining to something that he is manufacturing, or in which he has an interest, it should not be understood that the person, when talking before the mechanical engineers is talking for self in the matter, but it should be understood always that those who manufacture or have an interest in something are supposed to know more about it, and to have given more attention to that subject, and anything that they say should be always considered, I think; and while they have to bring self in, it is a very embarrassing thing; and that was my trouble this morning. I felt very much embarrassed. I came here for education, and to do all I could to extend any knowledge that I have, with the sole purpose of calling attention to facts, and I hope that it will be always be understood so; and I think, as I said at the start, that members should be supposed and expected to know more about subjects that they are devoting their lives to. And I believe Mr. Capen understands that while I am fervent in anything I may say—we have different methods of expressing ourselves; and while I do that honestly, with the intention simply of education alone, I hope it will be considered in that way; and I am very much pleased to know that I can give my views in a corrected form. [Applause.]

Mr. Durfee.—Mr. President: I am not a manufacturer of cranes, but nevertheless I have occasionally ventured to build a crane or two. I have put on the blackboard here a rough sketch of a traveling crane that I built over ten years ago for lifting the "rolls" from a "rail" and "top and bottom train." It is made of two timbers running lengthwise over the train of rolls; these are supported at the end by two posts which are properly braced on a sill. This sill is supported by wheels which run upon a track on the floor. The other end of these timbers are supported upon an overhead truck. Stiffness to the structure is also given by this brace. It is a hand crane, the infrequency of its use making it undesirable to apply power to it. The lifting chain fastens to a block here [indicating], goes over a pulley, and comes down here. This crane is applicable to hardly any other kind of work except the kind for which it was designed. It is now at work, answers its purpose very well, and is of very cheap construction.

(Mr. Durfee illustrated on the blackboard the construction of his crane.)

Another crane of different construction which I made some years before—in 1863—has a traversing carriage running upon two cast-iron girders supported upon posts. This carriage has on it a hoisting drum, actuated by a worm wheel and worm. This worm slides upon a shaft, there being a slot in the shaft and a feather in the worm. The worm takes an end bearing against brass collars that rest against some rubber springs, so that when the weight is lifted it has an elastic resistance, the worm being allowed to slide lengthwise on the shaft until the springs are compressed sufficiently to hold the weight, and thus the weight is lifted without a jerk.

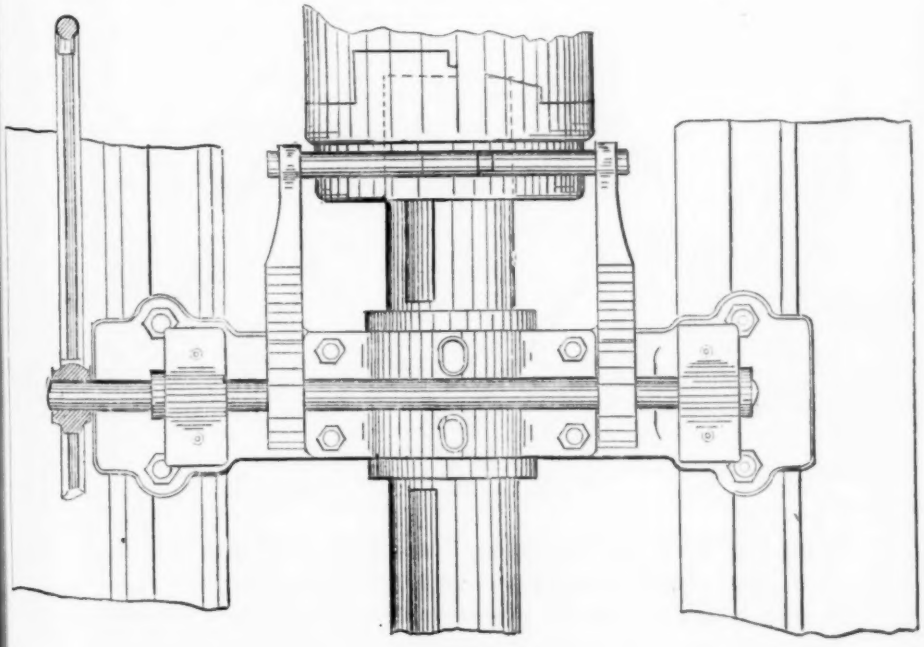
In conclusion, I will say that this traveling carriage and the suspended weight were pulled lengthwise the girders by precisely the arrangement mentioned in Mr. Towne's paper. There was a shaft at each end of the girders and two chains, which insured a parallel movement to the truck.

MECHANISM FOR MANŒUVERING CLUTCH COUPLINGS.

BY

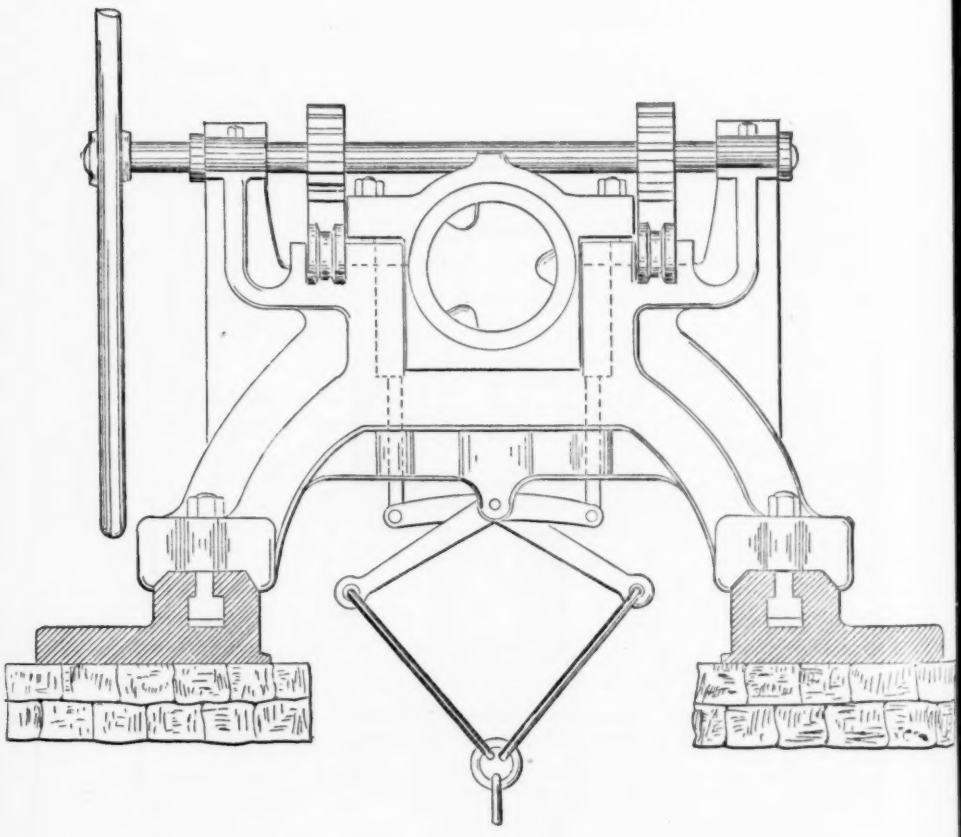
W. F. DURFEE, BRIDGEPORT, CONN.

THE method of manœuvering clutch couplings by means of a lever the extremities of whose forked shorter arm act within a groove surrounding the movable part of the coupling, has been a common mechanical expedient for centuries. Branca, in his work on Machines, published in Rome, 1629, gives two illustrations of its use, and for clutches of moderate size, transmitting but small amounts of power, this old and well-known device is in every way satisfactory. But when the clutch to be shifted is of large size and



great weight, as is the fact in many instances in modern establishments for the manufacture of metals, the great length and cumbrous character of the lever required, and the fact that it is

almost sure to occupy valuable space, constitute it, in many instances, a sort of negative nuisance—an uncouth and disagreeable necessity. For the purpose of avoiding the various objectionable inconveniences attending the employment of the lever for shifting large clutches, the writer many years since designed the mechanism

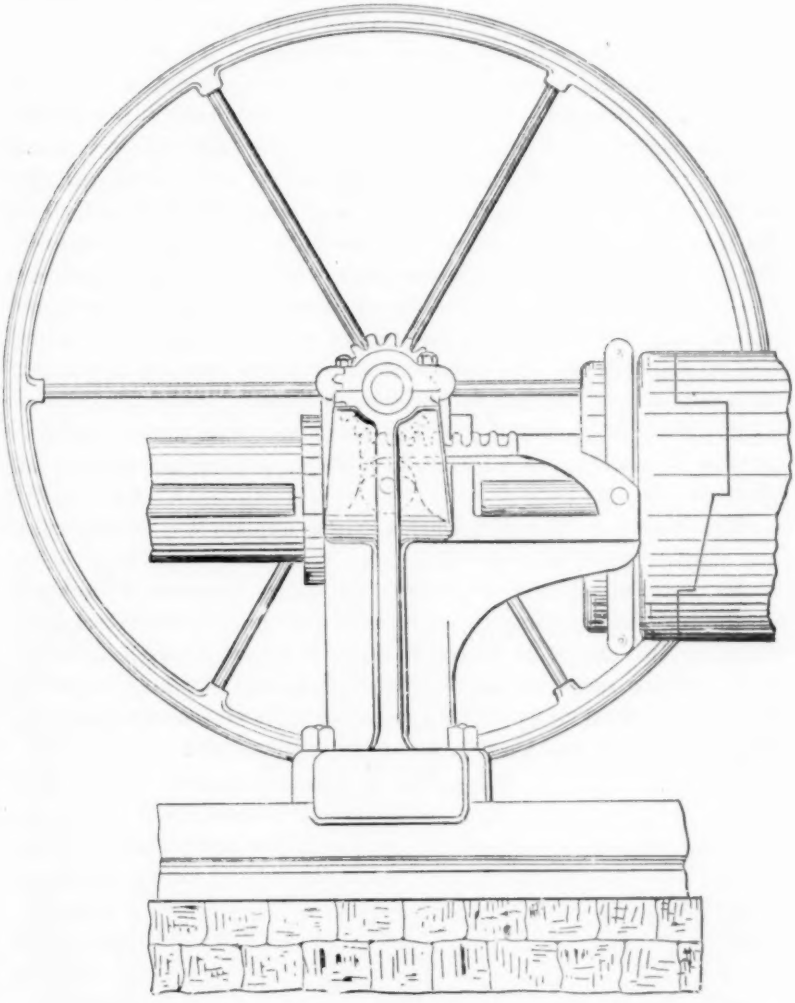


illustrated by the accompanying drawings, and from time to time, as occasion required, has employed it in his practice.

The drawings show the apparatus as designed for manœuvering the clutch coupling transmitting power to a "rail train."

The groove in the movable part of the coupling is occupied by a hoop of wrought iron, having trunnions on its outside at the extremities of its horizontal diameter; attached to these trunnions are the curved extremities of two rack bars, the lower ends of which are

terminated by plain horizontal surfaces, which slide when the racks are moved upon the similar surfaces of projecting horns attached to the stand which supports the "main spindle," on the right hand end of which the movable portion of the clutch is located; the



opposite ends of the racks are sustained by small grooved rolls which turn in bearings on the top of the stand before named. Above these rolls, with its axis in the same vertical plane that contains the axes of the rolls, is a horizontal shaft supported in bearings

in the upper ends of vertical horns cast on the stand before mentioned; on this shaft are placed two small pinions in gear with the racks already described. One extremity of this shaft is provided with a "hand wheel" six feet in diameter, the hub and rim of which are of cast and the spokes of wrought iron. It will readily be seen that by turning the hand wheel in the proper direction the clutch can easily be thrown in and out of gear. To the links suspended from the levers beneath the supporting stand is attached a weight sufficient to sustain (through the medium of the levers and the vertical pins attached to their shorter ends) the two parts of the "main spindle" bearing and the weight of the spindle itself; in fact, this weight is slightly in excess of what would be sufficient for that purpose, and it acts to keep the spindle in contact with the cap over its journal; by this arrangement the level of the centre of the "main spindle" can be easily adjusted by means of the bolts which hold the cap down, the weight acting through the lower half of the box and the spindle itself, to keep the cap in contact with its bolts. The box for the "main spindle" bearing is rather loosely fitted in the stand, and the whole combination has a manageable flexibility and adjustability which is very satisfactory in practice.

Mr. Walker.—Will Mr. Durfee please explain why he has long and short claws in his clutch?

Mr. Durfee.—The shorter claws are for the purpose of backing up the rolls, or reversing the rolls in case a "pile" gets "stuck" in them, or in case it is desirable to do it for any purpose. That is a common construction of clutch. It is not peculiar to myself. There are a great many of them in use in mills all over the country. That is, the long and short teeth are in common use.

ECONOMY IN LUBRICATION OF MACHINERY.

BY

GEORGE N. COMLY, EDGEMOOR, WILMINGTON, DEL.

In large manufacturing establishments the sum of money paid annually for lubricants is surprisingly great, and where oil is the lubricant the quantity wasted is a very large percentage of the total amount purchased.

Being convinced that such was the case, I endeavored to ascertain the actual quantity of lubricating material used in a given time on the various machines and in the various shops connected with the establishment at which I am engaged.

The result was startling, and the investigation proved that one of the most extravagant users of oil was the vertical engine used for driving the principal part of the works used for machine shop and bridge construction, etc.

The engine was nominally 60 horse-power, with 16-inch cylinder and 18-inch stroke, with an 84-inch diameter pulley, making 106 revolutions per minute, but the indicator cards were evidence of the fact that frequently 83 horse-power was produced by the engine.

Owing to the fact that the engine was overloaded, the crank-shaft bearings and crank pin gave much trouble by heating, and occasionally it was necessary to stop the engine during working hours.

The expense for lubricating oils on this engine during the month of May, 1882, was at the rate of $3\frac{53}{100}$ cents per hour of the time during which the engine was actually running. The oil used was cosmo-lubric No. 2, costing 65 cents per gallon, and the specific gravity of the oil was 26° Beaumé.

During June the oil cost $3\frac{91}{100}$ cents per hour run, and the engine was running 120 hours per week, or an average of 20 hours per day.

About the 1st of July I commenced using No. 10 lubricine-grease on the crank shaft bearings *instead* of oil, and the result was that the engine shaft bearings worked much cooler, gave no more trouble, and the cost of the lubricating material was reduced to $1\frac{15}{100}$ cents per hour run.

The crank pin at this time was still using oil, and continued so doing until October 9th, when I had a copper box attached to the stub-end of the connecting rod close to the crank pin with a $\frac{1}{2}$-inch tube connecting the box with the crank pin bearing, and No. 4 lubricine-grease packed in it. No. 10 lubricine was also applied to the guides for the crosshead, the result being that the cost of lubrication was still further reduced to $\frac{38}{100}$ of 1 cent per hour run, and the guides and pin worked much cooler than they did previously when oil was used.

A mixture of palm-grease and beeswax in proper proportions will compare favorably in efficiency with the lubricine-grease.

I have also found mixtures of beeswax and tallow or beeswax and suet to work very well as lubricants for shafting. The relative proportions must of course be made to suit circumstances.

During the past eight months the line shafting has been running *without oil*, depending exclusively on the mixtures such as already described. The shafting is all provided with ball and socket hanger boxes, and the top half of the box has two cups cast in it in which the grease is packed, each having a cast-iron cover fitting closely over it to keep out the dust. This cover is chained fast by a very light chain to prevent it from being lost or knocked down by ladders, etc.

The center oil hole, where a self oiler is usually placed, should be stopped up with a cork to keep out dust at that point, and the use of oil is not allowed on any of the shaft bearings where the grease can be applied.

By the regulations already described the cost of lubricants has been reduced $44\frac{6}{10}$ % in the cases noted above.

Means have been provided for using the grease on nearly all of the engines running at the works and on several of the heavy machines, the result being a saving of lubricant and cool running of the journals.

It is better when applying the grease to make large holes in the caps of the bearings (perhaps $1\frac{1}{4}$ or $1\frac{1}{2}$ inches diameter if allowable) and permit the grease to be packed directly on the journal surface. Where this cannot be done, a funnel-shaped cup is attached to the oil hole, in which is a copper rod, one end of which presses against the shaft while the other end passes through a spiral spring which is tightened to the required tension by a screwed cap. The cup is filled with the grease, and the rod passing through it melts the grease by the heat caused by the friction of the copper rod on the

journal, the spring being tightened sufficiently to produce the necessary friction on the end of the rod.

Plain copper boxes, however, are frequently preferable with lids to keep out dust. A piece of copper rod run through the center of the box touches the shaft, and the hole between box and shaft is made much larger than the size of the rod of copper, so that the grease can be well pushed down on to the shaft.

DISCUSSION.

Mr. Grant.—I would like to ask the gentleman whose lubricine he uses.

Mr. Comly.—The lubricine which we have used principally is sold and, I think, manufactured by R. J. Chard, No. 6 Burling Slip, New York City.

Mr. Grant.—We use it on our shafting, and it has run perfectly cool for 18 months. We have not used a drop of oil. We have one very quick running shaft (4,000 revolutions per minute), and it runs perfectly cool; we have not used a drop of oil on this shaft.

Mr. Comly.—This engine, as I said, was giving constant trouble, and it seemed as if it was overloaded. Sure enough, it proved that by our indicator cards; and we were agitating the subject of putting in a heavier engine right away, when I finally struck on this mode of lubrication and instead of the main bearing running hot all the time and keeping water on it, we removed all supplies of water, and it runs perfectly cool now, so that you can scarcely feel any heat there at all. The metal was brass originally, and ran hot; and in heating, of course, the tendency was to inclose on the shaft. The box was made in two halves, divided on a horizontal line, and of course, after being heated and enclosed on the shaft, it had to be loosened by scraping, and that was done several times, but it still ran hot. Then there was anti-friction metal put in the box composed of lead and antimony, which we found to be a very excellent anti-friction metal. But it still heated. Then we used very heavy bodies of cylinder oil—the heaviest oil we could get—and it still ran hot. But when we put the lubricine in, it seemed to remove all difficulty.

Mr. Grant.—I would like to ask the gentleman what the small springs are.

Mr. Comly.—The small spring is on a little copper rod which Mr. Chard furnishes with his cups. The end of the rod passes through a little cap, and the spring presses against the under side

of the cap. That cap is adjustable on the top of the cup, by means of a screw. The cap is to be screwed down just enough to produce sufficient pressure on the rod to keep the necessary friction on the rod. We generally prefer, wherever it is possible, just to put on a plain funnel-shaped cup with an inch and a quarter or an inch and a half hole, if the bearing will allow it, and just put a rod inside of that and nothing more, and may be once a day a man will go around and push the grease on it.

Mr. Grant.—Our cups are made with similar wire, but no spring; our line shaft is two and seven-sixteenths, running one hundred and twenty revolutions per minute. We have one that is running nearly 4,000, and we have never touched the rod in the cups since they were put on.

Mr. Comly.—When once the lubricine is well worked in and the dirt worked out, it just seems to lie there and keep the parts from touching each other, and they run with very little friction. One of the members asked me if I had taken any cards to indicate the difference in horse-power before applying the grease and afterward, and I remarked that I had not. The decrease of temperature of the bearings would seem to be sufficient evidence that the friction was decreased.

Mr. Woodbury.—Mr. President, the cost of an oil or a grease does not represent the whole cost which should be charged to friction. With a grease, the consumption is less, and the cost of the lubricant is much less than with oil; but in those instances where I have had some personal knowledge, the friction has been increased by the substitution of the grease for the oil.

This winter I went to a Fall River mill where the predecessor of the present agent had invested $2,400 in providing all his shafts with grease cups, and was using a grease which required a further supply only once in six months. The cost of that grease was much less than oil, but he had suspected that the friction was excessive, because he learned that his mill required more power per spindle than those of his competitors. And yet he hesitated to make a change, because it would cost $1,400 to provide the journals of those shafts with oil cups, and he would have to abandon the grease cups, making $3,900, in dead plant upon the oil and the grease cups. In one side of the card-room in the hangers of the line of the shafting, the grease cups were removed, and oil cups were run in their place. After it had been running for some time, I made some observations and found that

upon one side of the room where the shafting was lubricated with oil, the temperature of the frictional surface in the hangers was only eight degrees greater than that of the room. On the other side of the same room on a similar line of shafting running the same amount of machinery, doing the same work, and under the same supervision, but lubricated with grease, the heat of the frictional surface in the journal was 38 degrees greater than the temperature of the room. Now, that excess of heat means, of course, that the work of the engine was converted into heat, and it is certainly an expensive way to warm a room. (Laughter.) And of course it also represented an additional amount of coal under the boiler. The frictional surface was moving at the rate of about 175 feet a minute, and the pressure was 14 pounds to the square inch. I took samples of the oil away and tried them on an oil-testing machine which I have of my own make, and found that the friction of the grease at 128 degrees, 14 pounds pressure, 175 feet a minute, was 33 per cent. greater than the friction of the oil at the same pressure and velocity, and at a temperature of 98 degrees. Supposing that difference would hold good, it would warrant almost any expenditure in changing the oil cups and in using oil in place of grease. However, in using a grease or any lubricant, of course it is necessary to use one whose viscosity is enough to enable it to adhere to the surface of the metal. If the journal is rough or out of line or the pressure or velocity excessive, why, as a lesser evil, then a grease or a less fluid oil must be used. In the case of Mr. Comly's, a 26 Beaumé gravity oil was a rather light oil to use upon the engine. A 24 Beaumé is what is more generally used. In the light pressure journals used in cotton manufactories, there has been a great change to the lighter oils, within the last few years, because the diminution of friction warranted a greater expenditure of oil. One of the mills in Manchester, N. H., was operated by a water privilege which they were using up to their full limit. They changed their oil from about 28 to 32 Beaumé, and the diminution of the friction was so great that the mill ran and the production increased five per cent. In another mill where I advised a similar change, by substituting a mixture of paraffine oil and sperm for a mixture of paraffine oil and lard, the difference was so much that the agent of the mill said he didn't know what "co-efficient of friction" meant, but he followed my advice, and found that he could run his mill with his water-wheel gate partly shut. (Laughter.)

Had I fully known that this question was coming up in this form, I should have certainly brought some of my note books with me; but I trust that by the time of the next meeting you will make observations upon your own account, noting the cost and the quantity of power in connection with the cost and the quantity of the lubricant. For the heavier bearings and those running at excessive velocities, why, the heavy greases which are in use are the only method in which the work can be safely lubricated. (Applause.)

Mr. Comly.—In the use of lubricine and othes greases such as I mentioned in my paper, I will state that I have applied them to heavy machinery and line shafting and in warm places around engines where oil would run off quickly. It is not advisable to use heavy greases on *very light* running machinery, such as Mr. Woodbury refers to, namely, cotton mill machinery, etc. I quite agree with him in the importance of using light oils for such light work. The application of lubricants to machinery requires very careful management in order to obtain the most economical result, and it is equally as important to consider the saving of *power* as it is to consider the saving of lubricant. Care should be exercised to take both into consideration in choosing the proper lubricant for the various kinds of machinery, and always keep several grades of oils and greases in store with the strict understanding that *light* oils shall be given out for light running machinery, and heavier oils for certain other heavier machinery, while the greases or lubricine for still heavier machinery and shafting.

SOME OF THE MECHANISM EMPLOYED IN MULTIPLEX TELEGRAPHY.

BY

THOMAS WHITESIDE RAE, C.E., NEW YORK CITY.

THERE is a peculiar embarrassment attendant upon the preparation of a paper such as this, resulting from uncertainty in regard to its audience. One composed solely of specialists, versed in the elements and details of electrical mechanism, and only interested in new adaptations of them, must needs be impatient of explanatory descriptions which a physicist familiar with electrical laws and their mathematical demonstration, yet ignorant of the parlance of the operating-room, would esteem of material aid to his comprehension of the subject. Between these extremes is another class which, although unread in the vernacular of electricity, and comparatively indifferent to its scientific abstractions, is yet interested in that practical reconciling of its incompatibilities with common needs which raises it to the rank of a public utility, and a living force in the economy of life. To such an audience this paper is addressed.

Its province will be limited to brief historical notice of the conception of the idea of multiplex telegraphy, and of the important steps in its development: to a statement of the general problem in its several phases and their solution; and, finally, a concise description of the systems in widest present use, and their working.

The motive of research in this direction has been—as is true of nearly all cases of material progress—financial profit. The point is soon reached in any telegraphic conductor—dependent upon its conductivity, induction, and the skill of its manipulator—which is the ultimate of its power of transmission; and this had been some time attained—so far as existing conductors and instruments were concerned—when in 1853, Dr. Wilhelm Gintl, Director of Austrian State Telegraphs, conceived the idea of simultaneous transmission in opposite directions; thus doubling the capacity of his lines for business, with little or no additional expense for plant and equipment. He achieved certain encouraging results, but failed of complete success through an inadequacy of his method which it is needless to particularize here. Justice requires it should

be said that our own fellow-member Mr. Farmer antedated Gintl by a year in the quest for multiplex transmission, and it is only for the reason that he chose another path than the one whose persistent following has led to the successful working of the present day, that more extended mention is not made of his initial investigations. He also experimented successfully at a later day in the direction which Gintl pointed out.

Gintl's lead, although seemingly to no purpose, was taken up in 1854 by Carl Frischen, Inspector of Telegraphs in Hanover, and so well prosecuted that duplex telegraphy may be said to have sprung full-grown from his brain. Whatever has been done since, so far as single transmission in opposite directions is concerned, is, almost without exception, mere detail. His demonstration of the general problem is typical of all, and the basis of the methods in successful operation to-day. The conditions of the questions are, succinctly, that the receiving instrument at the near station shall—contrary to former practice—remain unaffected by movements of the transmitting key at that station, and yet be perfectly free to respond to currents sent from the far station, which must also find instant and unimpeded escape to earth. Figure 1, shown in a perspective which, so far as I am aware, has not yet been classified by any school of mechanical drawing, exhibits the *motif* of Frischen's solution

Before entering upon explanation, it may be of service to invite consideration of a few definitions which are the more necessary since even professional experts are at variance about them. For example, there is confusion in regard to positive and negative currents, positive and negative poles, and the positive and negative elements of a battery cell. Let it be understood that the electro-positive element is that which chiefly undergoes chemical decomposition, and the electro-negative element the one to which the products of chemical action tend and attach themselves. As a consequence, the current within a battery cell is always from the electro-positive to the electro-negative element. The current maintains its direction *without* the battery, and it greatly assists a comprehension of its behavior to associate the terms positive and negative with the idea of motion, *i.e.*, that the current moving *from* the cell is always positive, and the one moving *toward* it always negative. Corollary to this is the seeming paradox that the positive current takes its departure from the negative element of a cell, and *vice versa*. The substitution of the term *electrode* for *pole* favors

precision; and the understanding that the positive electrode is attached to the negative element of a cell, and the negative electrode to the positive element, may simplify description.

Fig. 1 gives a representation of one of the most prevalent devices in electrical mechanism—the electro-magnet, commonly called a relay. It is the chief dependence for opening and closing circuit at a distance, conveying and recording a signal, or maintaining a vibration, and derives its force from a current being conducted continuously around it in the same sense, and normally to its axis. This imparts polarity to the core, and it becomes a magnet. Frischen did not discard this device, but—bearing in mind the first condition of his problem, viz., that the receiving instrument at the near station should remain unaffected by movements of its own key, yet sensitive to impulses sent from the far station—divided the conductor encircling the relay-core, winding each half in a contrary direction. Now when the key *K* is depressed, the current from the battery *B*, connected with earth at *E*, passes along 1, *K*, 2, to *c*, where, each branch offering a path of precisely the same resistance, it divides equally and passes around the relay-core, equal in quantity and tension, but in opposite directions, each neutralizing the effect of the other, and leaving the relay quiescent. Thus the first condition is met. Of the divided current, one-half passes along the line *L* to the far station, making signal there, and the other goes through the variable resistance *X*, to earth. This resistance is equal to that of the line, and preserves the accurate balance needed for the working of the divided relay. It is made adjustable, to meet the varying condition of the line, instruments, etc., etc. This apparatus receives a signal in this manner. With K open, as shown in Fig. 1, a current arriving at R, from the far station, would pass through one coil of the relay, cause it to make signal, and find its path of least resistance to earth by way of *c*, 2, *z*, 3, *E*. With *K* closed at 1, the course would be *c*, 2, *K*, 1, *B*, *E*.

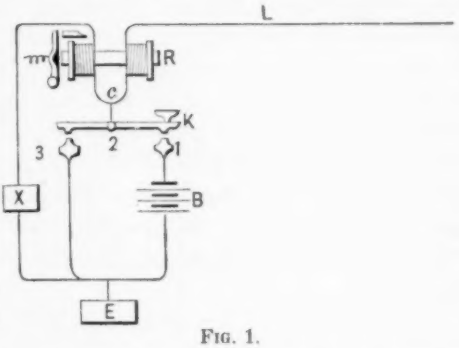


FIG. 1.

Fig. 2 shows two stations connected for transmission in opposite

directions by Frischen's method. The batteries *B*, *B* have their positive electrodes to the line *L*, and their negative electrodes to earth *E*. *R* and *R'* are the receiving relays wound with divided coils already described. The resistances for adjustment, *X* and *X'*, are regulated so as to equal in amount the resistance of the line *L* plus one coil of the relay at the far station.

Now, when the key *K* at station *A* is depressed, the current from battery *B* will divide at 3, one half passing by 4, and 5 to to the line *L*, through one coil of the distant relay *R'*, causing it to make signal, and thence by *IV*, *III*, *II*, to *b'* of the key-lever *K'* and *c'*, XI, to earth *E'*. The other half, starting from 3 at station *A*, will follow the other coil of *R* by way of 7, 6, 8, *X*, 9, 10, *E*. These two branches of current will have been of equal and

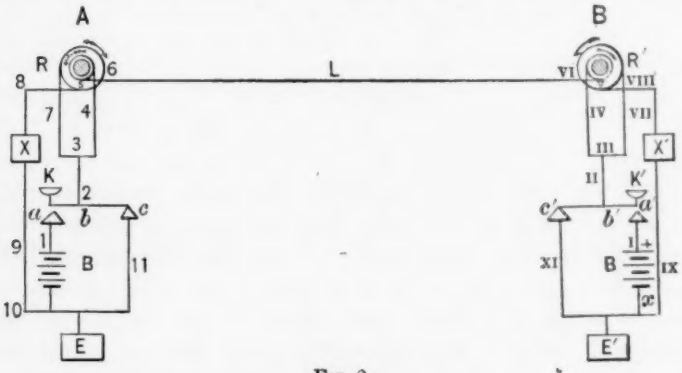


FIG. 2.

opposite effect upon *R*, which will have remained neutral, while *R'* influenced by the passage of a current through but one of its coils will have responded and made signal. If it had happened that *K'* at *B* had been depressed simultaneously with *K* at *A*, the portion of current entering the line from each station meets an equal and opposed current producing a condition of neutrality between the dividing points 3 and *III*. The other portions of current at both stations pass about their relays to earth—or rather, complete their circuits—through 7, 6, 8, *X*, 9, 10, and *VII*, *VI*, *VIII*, *X'*, *IX*, *X* respectively, making signals as they go, each corresponding to the movements of the key at the remote station.

There is another condition of circuit which exhibits the system at its worst, but which does not practically interfere with its usefulness. It is when the key at one station, for instance *B*, is midway in changing from rear to front contact—*c'* to *a'*—and *vice versa*. In

this position the current from *A*, having passed through the first coil of the relay, is arrested at *b'* and continuing by way of *VII*, *VI*, through the second coil, finds a path to earth by *VIII*, *X'*, *IX*, *X*. The electrical balance of the system is disturbed by the arriving current having to encounter a double resistance; for example, the addition of *X'*; but its effect on *R'* remains practically the same from its now following both coils of the relay; the influence of the halved current through the double coil being equivalent to that of the whole current through a single coil. The only detrimental result of this is that the derangement of electrical balance will affect, in some degree, the relay at the starting station; but in practice this has been found inconsiderable except at an unusually rapid rate of transmission.

Frischen's system, with unimportant modifications by various experimenters, maintained a feeble hold upon the public attention until 1872, when, after some years' study, Mr. Joseph Barker Stearns, of Boston, imparted new vitality to it by several additions, one of which effectually disposed of the prime obstacle to its general use and vastly extended its scope of operation. The difficulty was one inseparable from all conductors, all of which have a definite capacity, and, once charged, tend to discharge themselves by every exit available. Illustrating by Fig. 3, it can be readily seen that when, at the termination of a signal, the transmitter *T* establishes connection at the sending station between the line and earth, through the contact *c*, the former will tend to discharge itself by this channel as well as by the earth-connection of the distant station, and, passing, perforce, through but one coil to the relay, *R*, will produce a false signal which would interfere seriously with those arriving from the far station. In short circuits—within 400 miles of average air-line—this was not of much moment, but it effectually limited the application of double transmission to that distance.

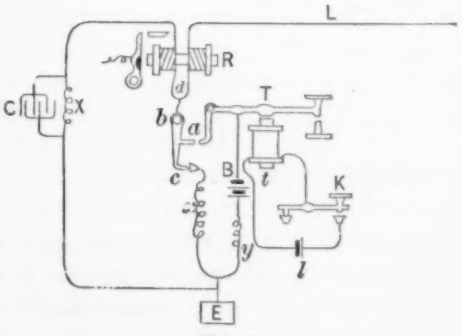


FIG. 3.

Stearns met the difficulty by interposing a condenser of the usual construction and of a capacity equal, at least, to that of the line, and as much more as experiment proves necessary. Such an one is shown at *C* in Fig. 3, and, with each signal sent through the line, receives through one half-coil of the relay, an equal amount of charge, which finds its way back by the same path when the transmitter again makes its earth contact at the same instant that the return discharge from the line is passing through the other half-coil, thus preserving the neutrality of the relay as perfectly as need be.

Another addition of Stearns—which, however, can hardly rank higher than a convenience—is the transmitter *T*, which is controlled by a key *K*, local battery *l*, and electro-magnet *t*. The first motive for introducing this was to avail of the possibility of reading by sound which it affords; but experience has shown that it also considerably increases the rapidity of transmission, besides sparing the operator much fatigue. With every depression of the key *K*, the electro-magnet *t* becomes active, and a current from the battery *B* passes through the transmitter lever which makes contact at *a*, at the same instant breaking it at *c* through oscillation of the

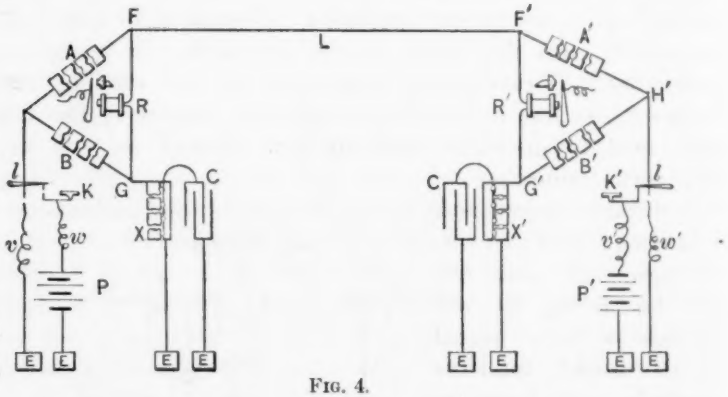


FIG. 4.

swing-bar about *b*, and passes in equal portions to line *L* and condenser *C* as before. The resistances *X*, *x*, and *y* are introduced to balance the circuit with as great facility and precision as possible.

Where this device has been employed with submarine lines, it has been found that some modification of it is necessary. This consists in largely increasing the condenser capacity and interposing resistance between it and the branch circuit, for the reason that the con-

denser discharges itself so much more quickly than the cable. To insure distinct signaling, the discharges must be equal in duration as well as in amount. The foregoing arrangement of Mr. Stearns, which he denominates the "Differential Duplex," is substantially that operated by the Western Union Telegraph Company; but he has a further development of double and opposite transmission which goes by the name of the "Bridge Duplex," and is shown in Fig. 4 as used by the same corporation. The illustration omits the transmitter—which is a customary attachment, but is inessential to a comprehension of the system—for the sake of simplicity. A description of one end of the circuit serves for both, and P, K, and l are respectively battery, key, and contact-lever; A and B adjustable resistance coils; GF the bridge and R the relay; X a variable resistance; C the condenser; w and v small resistances simply to save the battery the wasteful "short-circuiting" which may accidentally befall it while in action.

If resistance A stands in the same ratio to that of the line L, that resistance B does to X; when the key K is depressed the current will divide itself equally between these two paths, and the bridge and relay R be undisturbed. In the case of a current arriving from the far station, it finds two exits open to it—one through A, l, and v, or w, and P to earth; the other through R and X, or B, etc.

When several paths are open to a current, it apportions itself among them in inverse ratio to their several resistances, and adjustment of these for the case in question will invite the proper amount of current through R to produce the most effective signal. Here, as before, the corner-stone of the system, the condenser, plays its indispensable part, but while several distinct advantages over the differential method are conceded to it, its much less scope with equal battery power precludes its employment on long circuits.

Frischen's success with double transmission in opposite senses stimulated search for it in the same sense, and in 1855 Dr. T. B. Stark, of Vienna, solved the problem. His demonstration is given in Figures 5 and 6, showing, respectively, its arrangements at a sending and a receiving station. In the first case, Fig. 5, K and K' are two keys, the latter having at its rear a movable insulated earth contact which it presses at will against the anvils 5 and 6: otherwise the key is of the common pattern with all customary contacts and connections; 1, 2, and 3 respectively. There are two batteries, B and B',

the latter having double the number of cells of the former, and being controlled by key K', while B is controlled by key K. The connections are sufficiently evident to require no enunciation, and will be made clearer by remembering that the long thin lines in the group of parallels representing the batteries signify the copper plates and the short thick ones the zinc.

When K is depressed the current of B is from earth, E, through

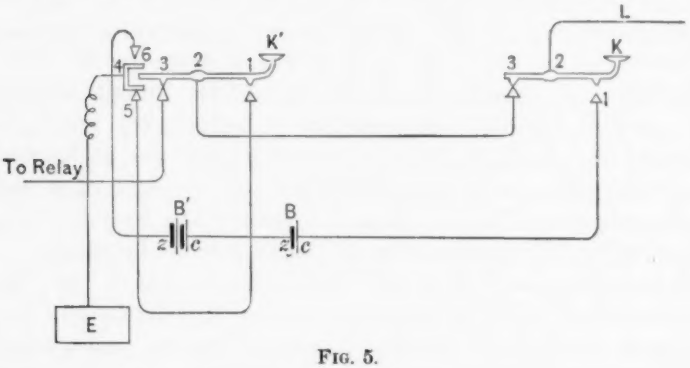


FIG. 5.

4 and 5 of K', across the post between the batteries, to z and c of B, 1 and 2 of K and on to line L. When K' is depressed the current of B' is from earth E, through 4 and 6 of K' and z, c of B' to 1 and 2 of K', and thence by 3 and 2 of K to line L. If both K and K' are depressed, the combined current of B and B' is from earth, E, by way of 4 and 6 of K', through both batteries and 1 and 2 of K to line L.

The foregoing three conditions of circuit produce as many currents whose intensities stand in the ratio of 1, 2 and 3, and which may be designated by Z, Z_1, Z_2. Their behavior at the receiving station, Fig. 6, will be as follows: Primarily, all currents pass through the relays R and R' which are actuated by a local battery B whose zinc pole connects with their levers and copper pole with their lever anvils. The relay R' has an additional coil, enveloping the first, in circuit with a resistance X and another local battery B' which is controlled by the lever of R. This lever is drawn to its contact by a spring which is so adjusted that, while it is insensible to the current Z, from the lesser battery of the transmitting station, it is affected by that of Z_1 from the greater battery or by Z_2 from both combined. The other relay R' is adjusted to respond to a weaker current as Z, consequently the depression of the key K at the far

station sends the weakest current, Z, through the line which continues through relay R without affecting it, but causes the more sensitive R' to close the local circuit including W', battery B, sounder S', etc., making thereupon the signal given by K.

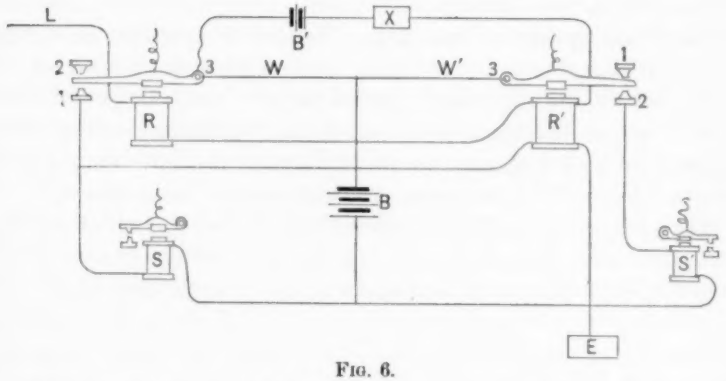


FIG. 6.

Should K' be depressed, the stronger current Z_1 flows and the lever of R makes contact at 1, closing the local circuit which includes battery B', resistance X and the additional coils of R' thus neutralizing the effect of the line current upon R'; since the batteries B' at both sending and receiving stations are of equal intensity and their currents traversing the double coils of R' in opposite directions become of no effect. The circuit including sounder S' being thus left open, it makes no sign. The movement of R which brought B' into action also completed a circuit including W, battery B, sounder S, etc., causing the latter to deliver the signal transmitted by K'.

The only other condition possible is when K and K' are depressed simultaneously. This sends the combined current of both batteries at the sending station, B and $B' = Z_2$, though both relays R and R' and the former as before closes the local current including B as well as that of the counteracting battery B'. The sounder of the first makes signal as a matter of course; and as for that of the latter, since we have seen that the intensity of the counteracting current about R' is only equal to S_1 and as S_2 traversing the other coil of R' is by construction equal to Z and Z', it is evident that R' will be actuated by a current equivalent to their difference, or Z, for which it is adjusted and which is the same that influences it when K alone is depressed. The circuit of R'

being thus closed, its sounder *S* makes the signal corresponding to the motion of the key *K* at the far station.

This handling of the question has disposed of all difficulties which are not, in our present state of knowledge, inseparable from the system; and, in fact, of all which are not, of necessity, insurmountable in the opinion of the most experienced and farthest-seeing investigators of the day. That of interruption caused by one key being midway between front and rear contact at the same instant the other is depressed may be cited as one of these as well as the interference arising from rapidly succeeding states of positive and negative electrification of the receiving instruments. For neither of these does there seem to be a remedy.

The successes thus far chronicled served to lead up to that seeming *non plus ultra*, the quadruplex system, or sending simultaneously over the same wire four signals, each pair in contrary directions.

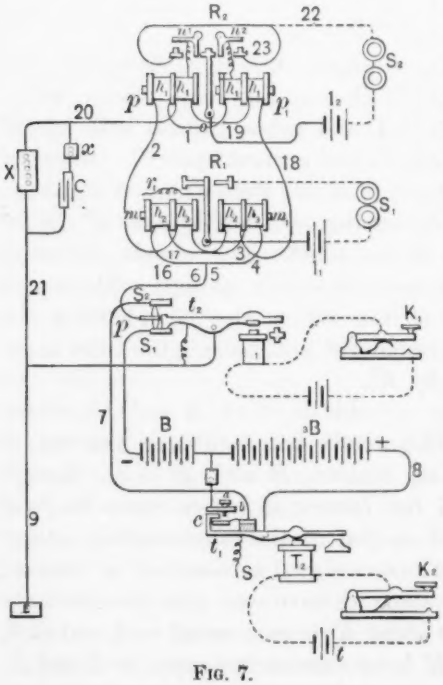


FIG. 7.

Fig. 7 shows the arrangement in widest general use, which is principally due to the genius of our fellow-member Edison. Quadruplex telegraphy is not a mere combination of the two methods of double transmission heretofore described. It has been found, necessary to employ two different principles of instrumentation designated the "double current" and the "open current." The former keeps the battery of the sending station in permanent connection with the line; signals being given by reversing the line current without breaking circuit. The relay which responds to these reversals differs from the ordinary type, in having a permanently magnetized armature and having no adjusting spring; its action being due to the nature of the

current and not to its strength. In the "open current," or single current system, signals are made by opening and closing circuit, or by increasing and decreasing a current, and are given by a relay with a neutral armature and a retracting spring. In the latter system, intensity of current is the sole agent. With these divers properties of current as a means, quadruplex telegraphy became possible. In Fig. 7 the receiving portion of the mechanism is, viz.: R_1 and R_2, differential relays with polarized armatures—the ordinary neutrally armed relay has been ultimately quite superseded; it having been found that the "differential" was of more convenient application than the "bridge" method—S_1 and S_2; the sounders and l_1, l_2, the local batteries. The transmitting portion is, viz.: K^1 and K_2 the keys with their local batteries; T_1 and T_2 the transmitters; B and 3 B, the main batteries. The resistances, X and x, the condenser C, and the earth plate E are common to both. The key K^1 effects a signal by reversing a permanent current—the polarized armature of the corresponding relay being attracted or repelled thereby. K_2 does so by diminishing the current or bringing at will both batteries, B and 3 B, or B only, into action. If, then, the ordinary plus sign be taken to mean positive and the ordinary minus sign negative, the intensity and character of the current pervading the circuit in every possible status of the instrument will be as follows:

K_1 open	K_2 open	+ 4 B.
" closed	" "	− 4 B.
" open	" closed	+ B.
" closed	" "	− B.

In the first position the positive current of both batteries flows to the line via earth E, 9, t_2, contact spring S_1; batteries B and 3 B, 8, t_1, c, b, 7, contact spring S_2, post p, 6, etc., and the polarized armature o of the relay R_2 is drawn against the contact lever n_1, and away from n_2, breaking the circuit of sounder S_2.

In the second position the line current is reversed, coming to earth E by way of 6, post p, contact spring S_2, t_2, and 9; and the armature o is impelled against n^2, again breaking the circuit of the sounder S_2, and consequently it remains unaffected by the stronger currents, whether positive or negative, which make signal on the relay at the far station corresponding to R_1.

In the third position the current intensity, no matter what its

polarity, is reduced from 4 to 1—by being given an earth connection by way of *a*, *b*, 7, etc., between the two batteries—and the springs of n_1, n_2, are too strong for it wherefore the local circuit of sounder S_2—or rather the one corresponding to it at the remote station, for the differential relays heretofore described are uninfluenced by the outgoing currents of their station—is completed through the double contact of armature *o*, and it obeys the indication of K_2.

The fourth position requires no further explanation, and in general terms the arrangement is such that R_1 is unaffected by the weak arriving currents, and its sounder S_1 is therefore quiet, while the stronger currents automatically eliminate S_2 from the train, only allowing it to respond to the lesser current, as already rehearsed.

The latest prominent example of multiplex telegraphy is that known as the Harmonic system, devised by Mr. Elisha Gray, of Chicago, in 1873. He discovered, in the course of his experimenting, that the vibrations of a musical reed in electrical communication with a charged conductor would produce synchronous movement in a vibratory surface at its remote end, keyed to the same tone as the reed, and in only such an one. The receiving instrument of this system is a thin metallic band stretched tightly between posts—by means of an adjusting screw which tunes it to any desired note—in front of the poles of an electro-magnet, which is traversed by the current pervading the vibrant reed and the line. The electro-magnet and metallic band are mounted on a thin resonant open box, which gives intensity to the tone, as does the body of a violin or guitar. So long as the reed at the sending station is vibrating and the current passing over the line, the resonator at the receiving station emits a continuous tone, which the key at the sending station breaks up into the dots and dashes of the ordinary telegraphic alphabet. Theoretically, the messages which can be sent simultaneously over one wire depend only upon the number of vibrant reeds and of resonators in circuit. In practice, eight messages, four in each direction, have been sent over circuits of one hundred miles and upward without any interference. Fig. 8 shows how the continuous vibration of the reed is secured. The reed *a* is fixed in the post *b* by one end, and vibrates under the influence of the electro magnets *e* and *f*, whose resistances are proportioned about in the ratio of 1 and 7 respectively as the result of experimental teaching.

Both are in circuit with a local battery B, and the one of greatest resistance, or longest helix, is naturally most effective. Throwing its resistance out of circuit would also intensify the other by permitting more current to flow through the latter. If, therefore, the local battery B^1 is brought into action by making a plug connection

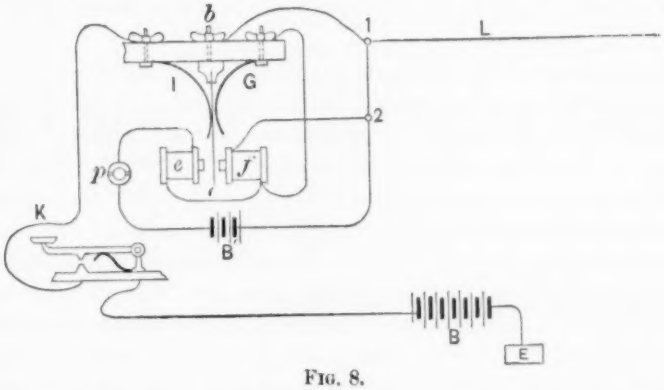


FIG. 8.

at p, its entire current will first pass through the magnet e alone, as f is shunted by the loop from contact spring G, resting against the reed, which offers a path of less resistance, and the current follows 2, 1, b, G, loop, etc. The action of e upon the reed a withdraws it from G, breaking the short circuit and bringing f into play, which, being the stronger magnet, again establishes contact with G, and again cuts itself out of circuit. This alternate action is maintained so long as the local current flows and the reed vibrates in conformity with it. If the vibrating reed a be put in electrical connection with a line wire L, via contact spring I, and a current from battery B be sent along it by depressing key K, the resonator of the same pitch—and only that one—at the far station will emit the same note; which the key K divides into conventional signals. Fig. 9 shows the method of connecting several reeds in telegraphic circuit. A' and B' are the reeds, the vibrating mechanism being omitted to avoid confusion. Each transmitting key, etc., is placed in a loop circuit around its own battery, and the main circuit runs through all, which is a feature of importance in obtaining the intensity of current which the system necessitates.

In conclusion, it only remains to say that the commercial value of such discoveries as the foregoing to telegraph companies, while exceedingly great, is not all that would appear at first glance. The

first inference on hearing that the working capacity of a line had been increased eight-fold would be that the profits were swelled in the same ratio, but this is not the case. To the credit side must be placed, of course, an eight-fold increase of receipts and a diminution to one-eighth of the charge for interest on cost, deterioration and supervision of a system of ordinary type and of equal capacity. Assuming that the average cost, in this country, of a mile

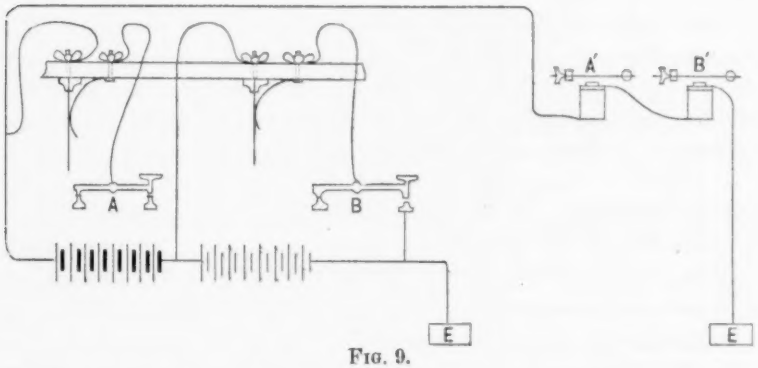


FIG. 9.

of well-built telegraph line is $250, its mean life-time fifteen years, and that the annual cost for inspection and repair is—which is the case—insignificant; the latter item will not amount to much. On the debtor side must be set down the salary of an additional operator for every time the capacity of the line is increased; since each transmission and reception requires the undivided attention of a clerk. The equipment of a station is also very much increased in cost. There has been, however, no radical increase in the rate of pay of the office *personnel* since the introduction of multiplex telegraphy, and if the existing scale left a reasonable profit in the days of single transmission, it is clear that stockholders in telegraphs are losing nothing under the new system.

SPIRAL SPRINGS—COMPRESSIBLE AND TENSILE.

BY

OBERLIN SMITH, BRIDGETON, N. J.

SPRINGS, using the word in the mechanical sense only, may be broadly defined as devices to store up power by means of the elasticity of matter. A convenient general classification would divide them into *fluid*, *semi-fluid* and *solid*. The first are, of course, compressible only, and the strain put upon them seems to be merely the crowding closer together of the molecules of a perfectly elastic substance, as air or other gas, in a state of confinement. In what we here call semi-fluid substances, of which india-rubber is perhaps the most notable example, the action appears to be somewhat of the same character, when the material is confined, but to consist chiefly, when not confined, of a very considerable distortion of shape, with a corresponding violent flow of its particles among themselves. In solid springs the particles approach, recede from, or slide past each other, to an amount within a fixed (the elastic) limit, precisely the same as in other solid structural members when subjected to stress. This stress is usually compressive, tensile, lateral or torsional—as regards the spring itself. Relatively to the piece of material of which the spring is composed, the stresses can of course all be resolved, as usual, into compressive, tensile and shearing.

In all the varieties of "flat" and "elliptical" springs the stresses are respectively compressive and tensile on either side of the "neutral line," exactly as in any other beam or lever. Belonging to the same class, but with modified conditions of leverage, are "coiled" (or flat spiral) springs, such as are used in watches, etc., and also such helical spiral springs as are used torsionally, examples of which may be seen in ordinary locks, in mouse-traps and for shutting doors.

It is, however, the object of this paper to treat only of such spiral springs as are strained in the direction of their axes, by either tension or compression. These are usually helical—that is, in the form of a cylindrical coil. The word "helical" would, in fact, have had a more exact meaning than "spiral" in the title of this

paper, as it does not include flat-spirals, but the latter word was used because it is the more popular and better known for the class of springs in question. The popular and expressive terms "push-springs" and "pull-springs" will herein be used for springs subjected respectively to compressive and tensile stress.

In designing machinery there is frequently a choice between the use of a spiral and some other form of spring. The former is undoubtedly preferable wherever it can be used to as good advantage. It has the merits of cheapness, beauty, compactness, durability and a capacity for uniformity of strain, not usually possessed by other springs. The push-spring is of course the simplest kind, and most desirable to use in cases where either push or pull can be applied to obtain a certain result. Where, in any structure, there happens to be already a hole within which, or a rod upon which, it can slide, it is the cheaper as well as simpler of the two. It has, however, the slight disadvantage of being liable to wear against its inside or outside guiding surface. This the pull-spring is not subject to, and in this respect is undoubtedly superior to all other forms of spring. Of the two most generally used methods of making the hooks at the ends of a spring of this kind, namely, bending the wire itself into a hook or reducing the coils in diameter and closing them around a separate headed hook of larger cross section, the latter is certainly preferable, especially if the spring is subjected to any swinging action which tends to wear the hook.

Regarding *methods* for coiling spiral springs, I call to mind three in common use. One is to wind the wire into a spiral groove, of the proper section to fit, turned in a mandrel. This is, however, an unnecessary trouble and expense, both in the construction of the tool and in getting the spring off of it. A second and just as satisfactory method is to wind upon a plain cylindrical mandrel, obtaining the requisite pitch of spiral by "feeding" the "tension grip" through which the wire passes along upon the carriage of an engine lathe, or equivalent tool. This is a cheap and convenient plan for machine-shop practice, where comparatively few springs of a kind are required. In cases where large quantities are required there is applicable a third method, which consists of forcing the wire through a spiral die by means of feed rollers. This delivers the springs in indefinitely long pieces.

In regard to *material* for spring wire (say of one-half inch diameter and below), there is probably nothing, on the whole, so satis-

factory as hard-drawn brass. For a cheaper article, hard-drawn iron and steel is good. Of course, more strength and elasticity can be obtained with the same weight of metal by using a tempered steel spring. The latter are not, however, as dependable as the others, on account of being liable to "temper-cracks" and unevenness or too great hardness of temper. They are undoubtedly best in many large springs (as car-springs, etc.), and in all cases where it is desirable to save room and dead weight. The popular prejudice in favor of "steel" springs is, I think, often caused by the prejudiced persons having been troubled with softer springs gradually "setting" under their load in consequence of improper design—there not being enough metal in them to allow of its strains being kept far within its *elastic limit*.

In respect to the *theory* governing the action of spiral springs, very little seems to be popularly known. It is a singular fact that few of the best known engineering books say anything about it. Having had occasion for some years past to make numbers of miscellaneous springs, I have endeavored to find some better principle to work upon than the time-honored "cut-and-try." A search through a number of works that happened to be at hand, by Rankine, Clark, Molesworth, Weisbach, Haswell, Nystrom, Trautwine, etc., revealed nothing but a few empirical formulæ regarding safety-valve and car springs—no principles being given. (It is but fair to state, however, that in some of their works Rankine and Weisbach do treat briefly the theory of the matter in question.)

A correspondence with some eminent experimentalists upon strength of materials elicited no information. Communication with various spiral spring manufacturers only developed the fact that this was entirely *out of their line*, and something in which they seemed to take no interest.

While studying this subject some time ago, the fact was pointed out to me by a friend that the action upon the wire (the word "wire" is herein used in a technical sense, regardless of its size or shape) of a spiral spring, while it is being extended or compressed, is almost purely *torsional*. Since this paper and some of the experiments below mentioned were commenced, I have seen a small book by John Perry, C.E., lately published by Cassell, Petter & Galpin, in which several pages are devoted to spiral springs, and this torsional action is demonstrated. Credit is given by the author to Prof. Thomson, of Dublin, who, it seems,

wrote upon the subject as long ago as 1848. The law of this matter is briefly thus:—When a *spiral spring* is extended or compressed, in the direction of its axis, the strains upon the *wire* are chiefly torsional. On the other hand, when the *spring itself* is subjected to torsion, the action upon the *wire* is mostly lateral or bending. In any push or pull spring the force is, in effect, applied in the line of its axis. If the ends of the wire are bent inward, so as to run across the spring in the direction of its diameter, the points where they intersect the axis are the places where the force acts. A line from one of these points out to the centre of the wire in the end coil that is to say—the *mean radius* of the spring—is the lever by which the wire is twisted. The length of this in inches, multiplied by the force in pounds, gives the moment of torsion in inch-pounds.

Thus, to ascertain the distance which one end of a proposed spring will move with a given weight attached, it is only necessary to take a straight wire of the same diameter, length and material, and, fixing one end, twist the other end with the same weight hung from the periphery of a wheel the same size as the mean diameter of the proposed coils—noting, of course, the distance moved by the weight. The results thus obtained are usually sufficiently correct for practical use, although there is a small element of error, because the action upon the wire is not wholly torsional—also from a change in the elasticity of the metal due to bending. The first-mentioned error would be *nil* if the coils were perfectly flat, but in proportion as they vary from this form, in conformity to the pitch of the spiral, there is a slight bending action in addition to the twisting.

To illustrate roughly the torsional action we have been considering, I hold in my hand a piece of lead rod about one-half inch in diameter and four and a half feet long. The ends are bent at right angles to form levers by which to twist it. It is painted black, with a narrow bright line scraped upon it along one side, in the plane of the axis. Here in my other hand I show a precisely similar piece coiled into a spiral three inches in diameter—the mean radius being the same length as the bent ends of the straight rod. This latter I now twist through an angle of 540 degrees, or one and a half times around, making the bright line appear as a spiral which records the maximum permanent twist. Lead was chosen in this case as having a very low elastic limit, so that it might "set," and thus record the strains. I

now extend the coiled rod to a setting distance of 14.13 inches, which is the distance the bent end of the straight rod traveled in going one and a half times around. I now uncoil the spiral, and if I succeed in bending it out without any torsional motion, the bright line will be found to be a spiral about the rod, closely resembling the line upon the other one.

I have recently made over 200 experiments upon pairs of specimens—one of each pair being straight and the other coiled. Both of a pair were of the same length, and were cut from adjacent portions of the same piece of wire. The amount of elastic angular motion produced by a given *moment*, in twisting rods of the same length, is, as is well known, inversely in proportion to the fourth power of their diameters. With different lengths it is directly as the length. This and other facts connected with torsional stress are the foundation of the various formulæ pertaining to spiral springs. These are proved more or less approximately by the 212 experiments recorded upon the large sheet I hold in my hand. This a careful averaging would no doubt show. Such discrepancies as remained could be accounted for by the small factors of error mentioned above, and by the difference of elasticity in the different specimens. As stated before, each one of a pair were contiguous in the original coil, but the pairs were of different sized wire, bought at different times—mostly from the same maker. The material used was chiefly hard-drawn brass. A few specimens were, however, of phosphor-bronze, soft iron, soft steel and tempered steel. The apparatus used for the coils was simply a fixed hook above and a hook below attached to a scale-pan for the weights. For the straight specimens an old lathe head, with very small journals to reduce friction, was fitted with a drill-chuck for gripping one end of the wire—the other being gripped by a special vise with "vee" jaws. Around a pully upon the lathe spindle ran a thin brass band, to the free end of which was attached the scale-pan. (It may be incidentally remarked that the lathe head used was one made by the writer many years ago when a boy novitiate in this very city of Cleveland.)

I had hoped to be able in this paper to present a tabular list of a part of these experiments, as well as a number of practical formulæ deduced from them and proved by actual trial. They should of course contain factors for correcting the errors spoken of. This must remain, however, for some future paper. An unexpected call upon my time prevented the proper working out of the matter.

This fact is of the less importance, as I have already trespassed sufficiently upon the valuable time of the Society.

DISCUSSION.

Prof. Robinson.—Mr. President, I was very much interested in the matter of the paper. I think that there is forthcoming from it much valuable information on the subject of spiral springs. It seems to be a subject upon which mechanicians are too often wanting in information. I would like to call attention to the fact that Rankine has been over pretty nearly all of the field of engineering, and, as we generally suppose, has overhauled the whole matter from one end to the other. We generally turn to him to find anything. I think it was stated here that the formulas for spiral springs were not found in several authorities, Rankine being included.

Mr. Smith.—The volume of Rankine that I had at hand was the one on "Applied Mechanics," but I did not search through all his books. I believe, as I said in the paper, that he does say something about it somewhere, but not at any great length.

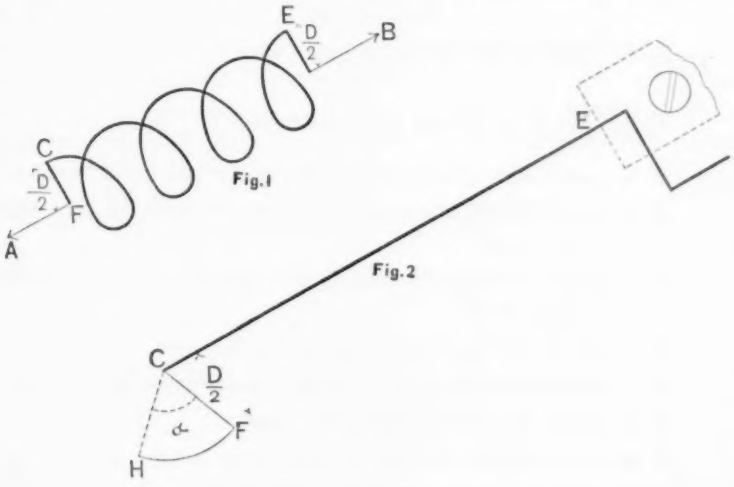
Prof. Robinson.—If we assume that he has overhauled the whole field of engineering, we would naturally expect to find something on spiral springs. In his "Machinery and Mill Work" we find the formula given. It is not deduced there; it is simply stated But I have examined it myself carefully, and find it to be correct, the reasoning by which the formula is deduced being exactly that given by the paper. The subject-matter leading to this result I have been in the habit of giving to my classes every year in a manner which I can illustrate on the board in a few moments. Suppose the spring to be constructed as has been illustrated by Mr. Smith, and as shown in the sketch, Fig. 1, the line AB being the axis of the helicoid.

Now the formula of Rankine is just as though this helicoid of Fig. 1 were regarded as straightened out, as shown in Fig. 2, and the portion CE treated as a torsional piece and the formulas for torsion adapted to it. To illustrate further, let CE, Fig. 2, be regarded as a straight wire of the same length, size and form of section as the wire composing the helix CE of Fig. 1. Also let CF, Fig. 2, be equal CF, Fig. 1, in length, etc., with CF at a right angle to CE.

Now, as has been fully and clearly shown by Mr. Smith, the

force FA, Fig. 1, produces torsion on the first short bit of the spring at C, reasoning which can be applied to any other small portion of the spring—indeed to the whole of it—and in the manner shown in Fig. 2.

The displacement of A, Fig. 1, regarding B as fixed, thus ap-



pears to be due to torsional elasticity, the fact being strikingly proved by the models shown and used by Mr. Smith.

Hence we are to look for the displacement of A, Fig. 1, in the corresponding arc FH, Fig. 2.

[The following has been added since the meeting, having been prepared in answer to the general invitation of the president for a subsequent forwarding of the complete discussions for use in the published transactions.]

Formulas for Helical Springs.

By aid of the considerations presented by Mr. Smith, and of the sketches of this discussion, Figs. 1 and 2, we are able to establish the formulas and rules for helical springs as follows:

Let D = diameter of the helix from centre to centre of the wire. If the wire is not round, take the centre of gravity of the cross section of wire for the centre.

d = diameter of the wire if round.

b and d = breadth and depth of the wire if it is rectangular or elliptical in cross section.

b = the side of a square wire.

I_p = the polar moment of inertia of the section of the wire.

$I_p = \frac{\pi d^4}{32}$ for round wire.

$I_p = \frac{b^4}{6}$ for square wire.

$I_p = \frac{bd}{12}(b^2 + d^2)$ for rectangular wire.

$I_p = \frac{\pi bd}{64}(b^2 + d^2)$ for elliptical wire.

E = coefficient of elasticity of the material of the wire.

E = about 30,000,000 pounds per square inch for tempered cast steel.

E = about 15,000,000 pounds per square inch for spring brass wire.

E = about 18,000,000 for spring copper wire.

R = modulus of rupture in pounds per square inch.

R = about 120,000 for tempered steel.

R = about 49,000 for spring brass wire.

R = about 60,000 for spring copper wire.

$\alpha = \frac{2h}{D}$. Where α is the arc to a radius unity, when $\frac{2h}{D} = 1$, the angle HCF = about 57.3°.

h = displacement of A, Fig. 1, or elongation of spring.

l = nearly πDn = length of the helical wire.

n = number of turns of wire in the helicoid.

P = pull or push in pounds upon the spring.

P_1 = greatest safe steady pull or push, on spring.

f = factor of safety, which probably should range from 3 to 8, according to the frequency of distortion of spring.

$\frac{R}{f}$ = greatest safe strain which the wire may be subjected to per square inch.

r_1 = the greatest distance from the centre of gravity of the cross section of the wire to the most remote edge of that section.

$r_1 = \frac{d}{2}$ in round wire.

$r_1 = b\sqrt{\frac{1}{2}}$ in square wire.

$r_1 = \frac{1}{2}\sqrt{b^2 + d^2}$ in rectangular wire.

$r_1 = \frac{b}{2}$ $\frac{d}{2}$ in elliptical wire, the greater being taken.

Then the formulas for torsion, which may be found in Prof. D. Wood's Resistance of Materials, are:

For any load.

$$P\frac{D}{2} = \frac{3}{8} E \frac{\alpha}{l} I_p ,$$

$$\text{or } P = \frac{2}{D}\frac{3}{8} E \frac{2h}{D} \frac{I_p}{\pi D n} ;$$

$$P = \frac{3Eh}{2\pi} \frac{I_p}{n D^2} .$$

For greatest safe load.

$$P_1\frac{D}{2} = \frac{4}{5} \frac{R}{fr_1} I_p ;$$

$$P_1 = \frac{2}{D}\frac{4}{5} \frac{R}{fr_1} I_p ;$$

$$P_1 = \frac{8}{5} \frac{R}{fr_1} \frac{I_p}{D} .$$

The greatest safe displacement, h_1 for any spring is:

$$h_1 = \frac{16}{15} \frac{\pi n R D^2}{Efr_1} .$$

When the load is suddenly placed upon the spring, causing oscillation, the greatest safe load is

$$\frac{P_1}{2} .$$

Example.—Given a tempered steel spring coiled from $\frac{1}{4}'' \times 1''$ flat bar steel with 10 turns, and to a diameter, c. to c. of $3''$.

Then $D = 3''$; $bd = \frac{1}{4}'' \times 1''$; $n = 10$; $r_1 = \frac{1}{2}\sqrt{b^2 + d^2}$;

$$I_p = \frac{bd}{12}(b^2 + d^2) .$$

Taking E and R as given and $f = 3$, we obtain

$$h_1 = \frac{16 \times \pi \times 10 \times 120{,}000 \times 9}{15 \times 30{,}000{,}000 \times 3 \times .515}$$
$$= 0.78 \text{ inch}$$

for the greatest deflection with a factor of safety of 3. The breaking deflection of the spring would therefore be $3 \times 0.78 = 2.34$ inches.

The load carried at the $0.78''$ deflection is by the formula P_1, or by the formula for P with the value $h_1 = 0.78$ introduced, found to be

$$P_1 = 916. \text{ pounds.}$$

If these results differ from practice, that is, if the load 916. pounds does not produce a deflection of 0.078″, and if the spring does not break with a load of 3 × 916. = 2,748 pounds and a deflection of 2.34″, it argues that the constants in the above formulas are not given correct values. The experiments of Mr. Smith will serve to give the desired values of the constants.

If the springs are made of round wire, the formulas become simplified somewhat.

For any load,

$$P = \frac{3E}{64}\frac{h}{n}\frac{d^4}{D^3}.$$

For greatest safe load,

$$P_1 = \frac{\pi}{10}\frac{Rd^3}{fd},$$

and the greatest deflection or displacement with safety,

$$h_1 = \frac{32}{15}\frac{\pi n R l^2}{Edf}.$$

These formulas, in substance, for round wire are found in Rankine's Rules and Tables, page 304, and other authors.

The 1st formula for greatest deflection, h_1 contains r_1 in the denominator, which is the distance from the centre of the section of the wire to the most remote point in that section. In a square wire this is greater than for a round wire of equal diameter, because in the square wire it is to be measured on the diagonal. As the other quantities in that formula do not change with the section, it appears that the deflection is inversely proportional to this distance r_1 for a spring of a given material.

Hence a spring of $\frac{1}{4}''$ square wire, for instance, will not stand as great a deflection as one of $\frac{1}{4}''$ round wire of the same material. Hence where a large deflection is the only object, round wire is the better.

This suggests an inquiry not only as to the relative carrying powers of springs of like material, but of square vs. round wire.

A comparison shows that a square wire will carry but 1.21 times as much as a round one, while the section is 1.28 times as great.

Mr. F. H. Richards.—The theory of spiral springs, I presume, is now pretty well understood, as a scientific matter relating to the torsion of the metal; but there are one or two facts that have been discovered practically in special machinery—manufacturers' machinery, particularly—that may be of quite as much interest.

Some twelve or fifteen years ago I had occasion to assist in de-

signing and building quite an extensive set of machinery in which spiral springs were an essential part, and in the investigations preparatory to the work it was found that it had been customary to use springs very much too small for the work. For instance, a mechanic, in building a machine, would put in a shaft, with perhaps a dozen cams on it. They were to him important pieces, and he made them large, with ample roll surfaces, and otherwise of good proportions. But the springs which produced the reverse movement were apparently neglected, or considered a small matter. Consequently there are frequent breakages. That has been the experience, I think, of nearly all mechanics using quick-running machinery having parts moved by springs. We found with springs of average material, such as could then be obtained in the open market, that if the spring were wound ten diameters of the wire and subjected to a motion not exceeding one-fifth of its length, it would be practically an enduring spring; and *vice versa*, if it was wound five diameters of the wire and subjected to a motion of more than one-tenth its length, it would not long endure the work. What I would call a good endurance for a spring, for such work, would be where one within those proportions makes, say, from sixty to a hundred strokes per minute ten hours a day 250 or 300 days in the year, and stands up to its work as a usual thing for two or three years.

In regard to the best way to put in a spring, I think that ninety-nine cases out of a hundred will require a pulling spring for endurance. A push spring, if a spiral of much length, it seems to me, is radically defective, both in theory and in practical work, because the spring, to do its work well and effectively, must have its axis in a straight line, and have it continue so, which with a push spring is practically impossible, for this reason: the wire, when wound spirally upon a core, fits the core, except a little expansion, of course, in unwinding; but when it is pushed together over the core it enlarges its diameter. This allows the axis to take a zigzag or curved course. Now this bending on the core produces a greater torsion at that part where the bending takes place, than the average torsion throughout the length of the wire, frequently straining it beyond endurance. Consequently, in several cases tempered steel springs have had to be abandoned after long trial. Sometimes, in order to secure endurance of the springs, and to get rid of the expense of constant renewals I have known machines to be re-designed and lengthened out to the extent of 30 or 40 per cent.

It is a matter of much importance in designing machines to provide room for springs of ample size.

I agree with the speaker that brass of proper temper, and well drawn, is the best material for ordinary springs for machinery. Next to that I think that mild steel well drawn will give the best satisfaction.

Mr. Smith.—Mr. Chairman, I would say to Mr. Richards that I have used a large number of push springs, necessarily; I could not use any other kind in certain kinds of machinery, and they do not work upon rods, but in holes. In that case we usually close the end of the spring in, conically, until the end coil is very small, or in some cases bend the end of the wire across, which, of course, gives the line of push in the axis, as it ought to be. In a case like that, where you can use a spring in a hole, it is all right; but a push spring upon a rod where you cannot do that is, I admit, defective in theory, as Mr. Richards says, although in practice we find many in use and get very good results. For instance, car springs, which are very short in proportion to their diameter, have just that defect. The pressure is brought to bear upon one side of the spring, and yet they seem to work well. Of course, the longer a spring is in proportion to the diameter, the less this evil comes in. I do not think the enlargement of a spring by compression, if the rod upon which it slides fits it properly, amounts to enough to be of serious import.

The matter of often-repeated use is a thing that probably has not been sufficiently investigated in regard to springs. I have made a few experiments with small springs, giving them about a million compressions, and although they were moved considerably within their elastic limits, they seemed, as a rule, to get shorter at the end of the millionth stroke. I did not, however, carry out the experiments far enough to obtain any reliable data upon the subject. The permanent set was partly owing to the spring wearing. It ran on a rod, and it wore a little upon the inside, which, of course, weakened it.

As to the principle governing the action of spiral springs, of course I did not claim that there was nothing at all published. I stated that I had failed to find it in looking over certain books I had at hand by Rankine, Clark and others. I believe that in some of Rankine's works the whole thing is treated, though I did not happen to have access to it when writing the paper. I only stated that this principle is not well known as a general thing, and

that all the spiral spring-makers to whom I wrote knew nothing about it whatever. In short, it has not become popular mechanical knowledge.

I have myself had similar experiences to those which Mr. Richards speaks of, in having to lengthen springs after they were first designed. I know a class of machines, built by manufacturers in New York State, certain springs on which were always "giving out," either breaking or setting so that they failed to do their work, and I know that a prejudice among buyers came up against that machinery built with those springs. The trouble came from the fact that they had not given length of spring enough for the amount of motion. And we found in a similar class of machines that we were building (although we put in much longer springs than the other parties) that the springs set. We nearly doubled the length, and they have ever since worked splendidly, and given no trouble whatever.

I want to ask Mr. Richards a question regarding those proportions he gave. You stated, sir, that where a spring was wound with a coil ten diameters of the wire, you could move it and allow its stroke to be one-fifth of its length. Now, did you mean its working stroke after it had been extended to the point where you start for the working stroke?

Mr. Richards.—I referred to the working stroke. The proportion of the extension was also determined approximately in these experiments, but I could not give the figures for that, but we did not use excessive extension as compared to the working length.

Mr. Smith.—Of course, for any *rule* in the matter it would be necessary to know first the extension, and after that the stroke out to the longest working point.

Mr. Richards.—My impression is that the total extension of the spring was one-fourth or one-third of its length; the spring was a pulling one, push springs not being used.

Prof. Webb.—I would like to state as to the treatment in Rankine, that it covers half a page, I think, but in Weisbach all kinds of springs are fully treated.

With reference to the proportions given by Mr. Richards, I understood that a spring wound upon a core with a diameter equal to ten times its own diameter—that was the proportion, I think—could be compressed one-fifth of its length without taking a set. Now, if I understand rightly, that does not allow for the number of

turns in the spring, which would seem to me to make an important difference. That is, a spring ten inches long might have ten turns in it, and it might have twenty. In one case it would have double the length of wire that it would in the other, and consequently it would have double the amount of compression.

Mr. Richards.—I did not mention that, for the reason we always in our practice wound the spring solid, the coils close to each other, for we had abandoned in our general practice the use of push springs on account of their unreliability. In some classes of machines great numbers of springs are used, and I know of one instance where about two hundred machines of one kind are running in this country, with probably twelve to fifteen springs each, of about the proportions I have stated, and the springs last for many years.

Mr. Woodbury.—Mr. President, those who desire to look up the formulæ relative to springs will find the subject of both spiral and coil springs treated more fully in "Der Constructeur" by Reuleaux, than in Weisbach or Rankine.

Mr. Grant.—In the works of the Pratt & Whitney Co., there are five automatic tap thread machines running. They have springs that run on a rod—push springs. The springs are wound open, and are about a tenth of an inch in diameter; that is, the spring wire is about a tenth of an inch in diameter, and they are wound open a trifle more than the diameter of the wire, and are not over six diameters in size. Those springs are compressed to less than half their length; and they have been running to my knowledge, five years, making perhaps twenty strokes a minute, and they are just as good as they ever were, for all I know.

Mr. Richards.—I would like to ask Mr. Grant how large a number of those springs were in use, so as to get some data as to the percentage, or value of the test in that case.

Mr. Grant.—There were five machines running and they had two springs—ten springs. I think it makes a great difference in the way the springs are tempered.

Mr. Smith.—Speaking of temper, I would just say, that tempered steel of proper quality is, I believe, the most elastic metal in existence; and springs of that kind would stand a great deal more compression, relatively to their diameter and the diameter of the coils, than brass springs would; but I believe that brass springs are cheaper and more reliable where you can get room for plenty of length and plenty of diameter in proportion to the stroke, so as not to

bring them down to the elastic limit. No doubt the springs Mr. Grant speaks of, if they were made of brass, would have set long ago; but if there had been room for them the brass would probably have been as good or better. In any case where I speak of brass being better, I mean on account of its freedom from temper-cracks and extra brittle spots, which cannot always be discovered during inspection, and may cause breakage at some unexpected time—perhaps after long use.

Mr. Capen.—I would ask Mr. Grant to repeat what he said as to the amount that the spring was open after being closed. I did not quite get it.

Mr. Grant.—The distance between the coils when open was about once and a half the diameter of the wire. The springs were compressed to less than half their length. That was all the room we could possibly get in the spaces the springs were in.

The President.—If there is no further discussion on this subject, the Chair would remark, that having occasion some time since to design some springs for pump valves which necessarily must be brass springs on account of working in water, he investigated all the formulæ that we could find—those of Rankine, Weisbach and Reuleaux—and springs were constructed and tried. Finally a formula which was given me by Mr. Atterburg, one of my draughtsmen (taken from a German text book, I think), came nearer than any other, and was quite accurate. These springs were quite light. They were push springs. They were one and one-half inches in diameter, made of wire a little less than an eighth of an inch in diameter, and were some three inches long. The lift of the valve was about six-tenths of an inch. The extreme pressure on the spring was not, I think, over six pounds. We found that Mr. Atterburg's formula was nearer than any other. I will try in printing the remarks on this subject to give that formula. I do not remember the name of the work, as I do not read German. But it will be interesting, perhaps, to the society to know that Mr. Corliss in his pumping engines uses a spring made of phosphor bronze about one thirty-second of an inch thick and some quarter of an inch wide, the object of this spring—it is a push spring,—being to keep the valve from lateral movement. The idea is that in case any foreign object should get under the seat the valve would come down over the spot until the next stroke, when the piece would be washed out without causing the valve to leave its line of movement. The springs and valves are of the same diameter, about two inches and a half

at the base. The upper diameter of spring is possibly an inch and a half, and the whole height of the spring is some inch and a half. I do not know the endurance of those springs, but I should suppose that in one of the engines mentioned there were from forty to fifty revolutions made per minute, and that probably a set of springs will last a year. You can readily see with an engine running twelve hours a day how many compressions the spring is subjected to.

Mr. Grant.—Mr. Pickering has had a push spring in operation. He might give us his experience.

Mr. Pickering.—I beg pardon, it was a torsional spring.

The President.—I think we shall all admit that this is a very important subject, springs being an essential feature in mechanical construction, and if any member who has information on the subject will print the remarks which he might wish to make as to his views on this subject, it will be a valuable contribution to the subject.

THE BOWER-BARFF RUSTLESS IRON PROCESS.

BY

GEORGE W. MAYNARD, OF NEW YORK.

THE substitution of costly and not easily oxidized metals for iron in structural, engineering and art work has been rendered necessary because of the difficulty which has always been experienced in so protecting the surfaces of cast or wrought iron as to prevent the corrosive action of the atmosphere or water. The multitudinous devices in the form of paints, coating by immersion in molten metals (galvanizing and tinning), or the electrolytic deposition of metals have at the best been very unsatisfactory expedients.

With the exception of the noble metals, iron far exceeds all others in the ease with which it can be manipulated and converted into artistic forms, as is shown in the beautiful hammer work of Germany and Belgium, and the fine castings of Ilsenburg and Coalbrookdale in Europe, and Poulson and Eger, the Magee Furnace Co., the Yale Lock Manufacturing Co., and others in this country. But rust has come in to spoil many a beautiful work of art, notwithstanding the veneer of copper, brass and nickel, so that it began to look as though iron was doomed except for such constructive work as would be hidden by brick and mortar. It is well known that the architect shuns the use of iron where it comes in contact with stone, owing to the unsightly streaks of rust which speedily deface the surfaces of both the iron and stone. Any device which will absolutely prevent rust, without marring the beauty of the iron must be hailed with delight by the architect, manufacturer and engineer. The coating must admit of easy application, must be pleasing to the eye, must be susceptible of taking and holding paint—where, for any reason paint becomes necessary—must not injure the iron, and must be cheaply and quickly applied.

These requirements are complied with in a marked degree by the Bower-Barff Process.

The process has been so long before the public and has been so fully described in the able papers of Mr. George Bower, read before the Iron and Steel Institute of Great Britain in 1881, and before the Society of Engineers in London last month, and by his son, Mr. A. S. Bower, before the American Institute of Mining

Engineers in February last in Boston, that much which I have to say will of necessity be extracted from these papers because they cannot well be improved upon. I here make a general acknowledgment of my obligation to these gentlemen.

In 1876 Prof. Barff read a paper describing his process before the Society of Arts in London, which created a great deal of interest at that time.

The Barff process consists in placing the objects of iron or steel into an iron muffle, which is heated by the external application of heat, and then, when at a sufficiently elevated temperature, depending upon the nature of the articles to be operated upon—whether cast or wrought iron, heavy or light—steam superheated up to about 1,000° Fahr. is turned into the muffle, and the formation of magnetic oxide immediately commences. The heated iron or steel decomposes the steam, taking up certain definite proportions of oxygen forming Fe_3O_4 or magnetic oxide. The thickness of the coating depends upon the duration of the operation, and the time varies from six to eighteen hours. Magnetic oxide so formed is in its substance black, but when the articles first come out of the muffle they have a bloom on them very much like that upon a ripe damson.

The Barff process, as it was carried on by the professor, was necessarily an expensive one, because there was required first the steam, then the superheating of it, and the external heating of an iron muffle, which had not a very long life. Wrought requires less heat than cast iron, so that a muffle lasts much longer for wrought alone than if it has to be used for both. A good deal of beautiful work was done during the three or four years the process was worked by the professor, but it was not taken up by the iron trade, on account of its cost.

At one time it looked as though what had promised so well was to turn out commercially unsuccessful or at best to have but a very limited application.

The ingenuity and perseverance of the Bowers, father and son, came to the rescue, and as a result we have the triumph of to-day as is shown in the samples exhibited.

Mr. A. S. Bower in his Boston paper gives a very interesting account of the many difficulties with which he had to contend before arriving at satisfactory results, and then proceeds to give an account of the present method of treatment and the chemistry of the process.

There was commenced a series of experiments with carbonic acid chemically produced by the decomposition of chalk, the idea being that three equivalents of iron would unite with four of carbonic acid, forming one equivalent of magnetic oxide and four of

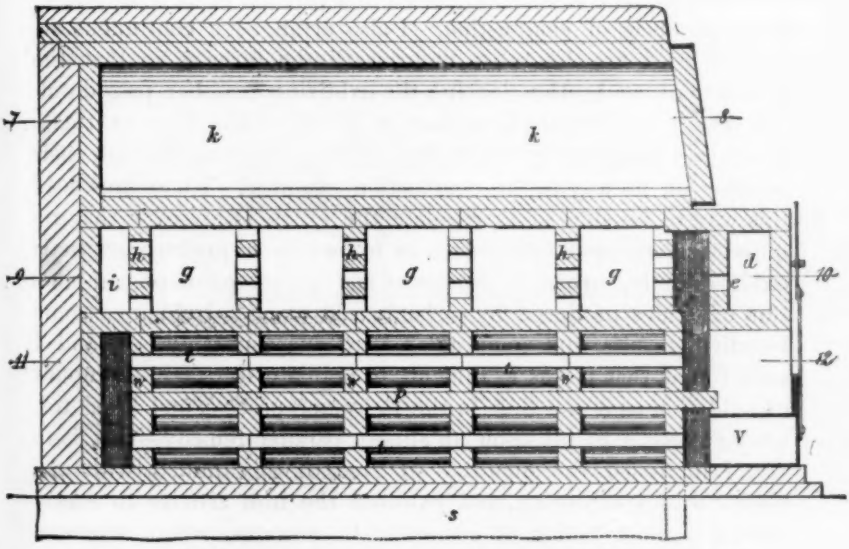


FIG. 1.—LONGITUDINAL SECTION OF BOWER FURNACE ALONG LINE 1—2 IN FIG. 3.

carbonic oxide, if the heat were sufficiently high. This reaction is expressed symbolically thus: (1) $3\,Fe + 4\,(CO_2) = Fe_3O_4 + 4\,(CO)$. This is the simplest action that could take place, but it was evident from the results that something quite different was obtained, inasmuch as the coating was very light in color, pleasing to the eye, but easily removed, and in that sense entirely differing from the articles you see before you. This coating, from effects exactly similar and designedly produced by a studied manipulation in the furnaces in successful operation in England, France and here, proves pretty conclusively that carbonic acid, practically pure, produces upon iron, at an elevated temperature, a film which is, in composition, a mixture of *Fe O* and Fe_3O_4, or, at all events, it is nearer the metallic state than is magnetic oxide. But even supposing that the results obtained by the carbonic acid had been successful as then carried out, the objections referred to concerning the air process would still exist, as external heat and a closed iron

muffle would always be necessary. I therefore proposed to use a fuel-gas producer, similar in principle to the Siemens' generator, but altered practically to suit other requirements, to burn the combustible gases thus produced with a slight excess of air over and above that actually required for perfect combustion, and to heat and oxidize the iron articles, placed in a suitable brick chamber, by these products of combustion. I also arranged a continuous regenerator of fire-clay tubes underneath the furnace, so that the products of combustion leaving the oxidizing chamber passed outside the tubes, imparting a portion of the waste heat to them, which was taken up by the in-going cold air passing through their interior on its way to the combustion chamber. I had hoped in this way to be able so to regulate the excess of air over that required for complete combustion as to be able to produce magnetic oxide directly, instead of the lower and useless oxide or combination of oxides produced by carbonic acid alone. I obtained some beautiful results, and some again were unaccountably bad, and I soon found that it was as difficult to regulate the precise amount of oxidation as it was first in the Bessemer process, and I was fortunate enough to hit upon an almost parallel remedy—that is to say, I increased the quantity of free oxygen mixed with the products of combustion, and oxidized the iron articles to excess during a fixed period of generally 40 minutes, when magnetic oxide was formed close to the iron and sesquioxide over all. Then for 20 minutes I closed the air inlet entirely, leaving the gas-valve open, and so reduced the outside coating of sesquioxide to magnetic oxide by the reducing action of the combustible gases alone.

The excess of oxygen in the first instance produces Fe_2O_3, or sesquioxide of iron, and the under surface of this, being in contact with metallic iron, undergoes reduction to magnetic oxide in the following manner: Four equivalents of sesquioxide unite with one of metallic iron, forming three equivalents of magnetic oxide, or, symbolically (2) $4\,(Fe_2O_3) + Fe = 3\,(Fe_3O_4)$.

When deoxidizing by combustible gases, consisting mainly of carbonic oxide, three equivalents of sesquioxide unite with one of carbonic oxide and form two equivalents of magnetic oxide and one of carbonic acid, and, symbolically (3) $3\,Fe_2O_3) + CO = 2\,(Fe_3O_4 + CO_2)$. Another method of reduction is by carbon itself, when the formula stands thus: (4) $3\,Fe_2O_3 + C = 2\,(Fe_3O_4) + CO$.

Formula (3) is also the reaction when rusty iron is reduced by producer gases, and which consist largely of carbonic oxide, and by

the specimens exhibited it will be seen that articles completely pitted with rust may have their surfaces rendered rustless. In this case the periods of oxidizing and deoxidizing are reversed—that is to say, the latter occupies 40 and the former 20 minutes. No oxidizing is theoretically necessary, but practically a certain amount is requisite to keep up the heat in the chamber, which, of course

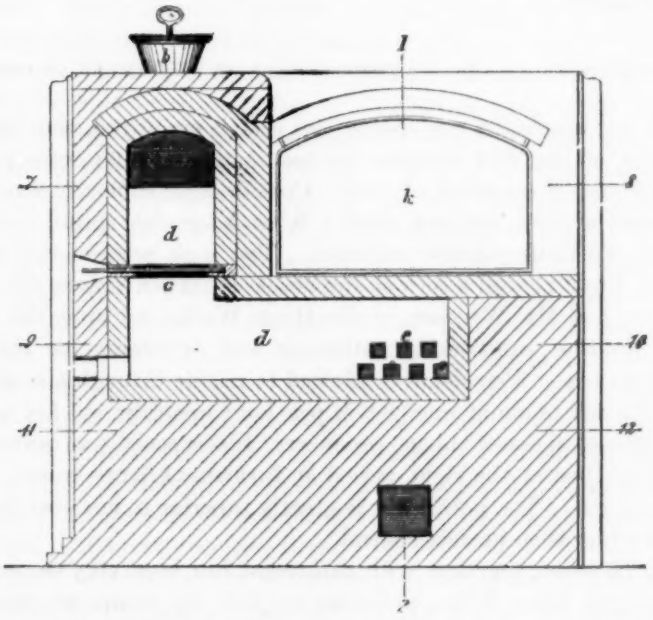


FIG. 2.—TRANSVERSE VERTICAL SECTION ALONG LINE 3—4 IN FIG. 3.

could not be done unless combustion took place some time or other. I only mention the reduction by carbon as exemplified by Formula No. 4 because, while experimenting with a furnace, I was asked by the proprietors of a valuable red-oxide deposit, which was found in so finely divided a state as to be capable of being used at once as a paint, whether I could reduce it to a magnetic oxide. I tried to do so by carbonic oxide, but I found that only the surface of it was affected, and that even this, when taken out of the furnace, speedily returned to its original red color by the combined actions of the hot unconverted material underneath and the air above. It will be found from formula (4) that $2\frac{1}{2}$ pounds of carbon are required to reduce 100 pounds of red oxide. This I mixed intimately, in the shape of powder, with the red oxide, brought the mixture to a red heat and

the result was black magnetic oxide. Not only this, but by adding more carbon I could make the color lighter and lighter until it was almost identical with the coating produced in my previous experiments with carbonic acid, and by reducing the quantity of carbon below 2½ per cent., various shades of purple were obtained, the red appearing more and more prominent as the quantity of carbon was diminished.

OBSERVATIONS AND IMPROVEMENTS MADE IN THE AMERICAN PRACTICE.

1. In England a non-coking gas coal is employed, and the producers of the first furnace erected in this country were proportioned for this variety of coal. Considerable difficulty was experienced at first, and not until a West Virginian splint was tried were satisfactory results obtained. The high price of this coal in New York proved a serious drawback to its continuous use. Mr. Bower and Mr. Winslow, of the Hecla Works, hit upon the happy expedient of substituting anthracite and petroleum for the bituminous coal. Petroleum is allowed to trickle through a small pipe at the rate of about one gallon per hour upon the red hot surface of the coal in one of the gas producers. It is especially advantageous, because just at the right period it furnishes a large volume of reducing gas. The petroleum is greatly superior to any coal, because it is under such perfect control.

2. Sawdust, together with anthracite, has been very successfully employed when it was necessary to raise the temperatures of the furnace in a very short time. As the combustion is absolutely controlled by proper valves, *three bushels* of pitch pine sawdust have been gradually consumed during 1½ hours.

(3) The most important improvement made in this country is the use of superheated steam in the Bower Furnace in finishing the treatment of castings. Heretofore such treatment has consisted in successive oxidations and reductions. It is found that after the last reduction the admission of superheated steam for a period of 1–2 hours is very advantageous. It re-oxidizes any over-reduced coating and insures a coating of constant quality, besides imparting a fine luster to the coating and noticeably increasing its tenacity. This improvement was made by Mr. Bower before his return to England.

(4) A low temperature, not above incipient red, is required in obtaining good results with polished work, wrought or cast. Con-

tinental practice is reported to have shown that the treatment of iron with steam superheated to a higher degree than the temperature of the articles themselves produced the best results. The same has been found the case in this country. A charge of polished ware is run into the furnace which is at a certain temperature—say red heat—and the metal soon absorbs the heat and reduces the temperature. The combustion chamber and regenerator, however, hold their higher temperature and effectively superheat the steam before it reaches the iron in the furnace chamber. By simple trials the quantity of heat absorbed by a given charge of iron can be ascertained, and thus a practical means is afforded for guidance as to the temperature to which the furnace must be raised before introducing the charge. By this practice the cost and other disadvantages of an externally heated muffle are obviated, while treatment in the direct Bower Furnace can be carried out without heating the charge by burning gases. This is considered an important advance in obtaining good results with polished articles, for the producer gases, especially those from hot anthracite fires, are apt to have a cutting or roughening effect on fine ware. Polished work treated in this improved manner, and then rubbed up with flour-emery and oil, has a tenacious coating of a remarkably brilliant blue-black luster. Such treatment, however, is not required on ordinary iron for which the operation is accordingly carried on at higher temperature and in relatively shorter time.

(5) Articles which are to be exposed to active rusting influences are treated for 7–9 hours, while such as are intended for indoor exposure receive but a very thin coating in an operation which lasts from 2–4 hours. Such articles, subsequently polished, cannot be guaranteed against prolonged outdoor atmospheric influences. Minute particles of the *thin* coating are apt to be removed in the polishing process, exposing the metallic surface to oxidation. The treatment in the case referred to is rather for the purpose of ornament than for very thorough protection.

(6) Foundry sand, if left on the castings, is not in itself injurious, since the magnetic coating forms beneath it. It has, however, a red, rust-like appearance after the treatment, and this impairs, for many purposes, the market value of the articles. A very simple, cheap and effective means of removing the most firmly adherent sand, especially in castings having an irregular surface, is a steam sand blast, or, better still, a steam and water sand blast in a small apparatus having the form of an injector which drives a jet of hot

water and sand against the casting. This contrivance, as well as the other improvements here mentioned, are due to the able and active interest of Mr. Winslow, of the Hecla Iron Works of Brooklyn.

(7) The temperature for treating ordinary rough cast and wrought iron being a good red, precaution must be taken to support the articles with some degree of uniformity in order to guard against distortion. No difficulty has been encountered on this score. Very thin iron, such as sheets, is preferably treated at a dull red; there

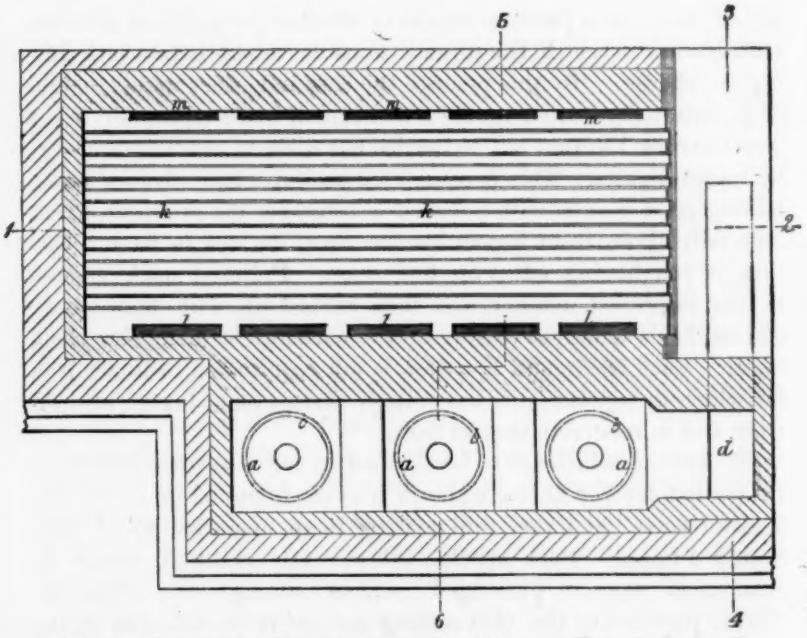


FIG. 3.—HORIZONTAL SECTION ALONG LINE 7—8 IN FIGS. 1, 2 AND 5.

is then no chance of buckling or bending, even without much supporting. As a rule it is not found desirable to treat in one charge both very light and very heavy articles. The former become overheated and distorted at a temperature which is just right for the latter. For many articles the temperature can without injury be raised sufficiently high firmly to bind two pieces of iron by means of the oxide as cement. This welding property promises to open a wide field of utility in treating sheet iron pipe, cans, etc., which require water-tight joints.

(8) If it is desired to treat at one and the same time both polished

and ordinary ware, a wash of plaster of Paris, applied to the polished surfaces, prevents the cutting or roughening action of the hot gases upon them.

(9) Plaster of Paris is also used, in moderately thick coating, to protect the screw threads of bolts, gas pipe, etc., from an energetic oxidizing action. A thin, but perfect coating is formed beneath the plaster—ample to protect the threads until they are finally screwed up—while not thick enough to create difficulty in fitting or to require a special threading in ordinary architectural or stove work—cases in which screws and nuts always have a certain amount of play. For small bolts and nuts, closely cut, is has sometimes been found advisable, though not absolutely necessary, to cut the nuts with a taper tap. In more accurate machine work the proper bolt holes are drilled before the oxidation. Subsequently each hole is reamed out (by which the coating is removed) and the thread accurately cut. The screw joint must be protected from rust by oil in the usual way.

The following extracts are taken from an article which appeared in the *Revue Universelle*, published in Belgium.

After describing the furnaces and chemistry of the process, the writer says:

The rustless articles withstand the effects of heat, while coverings of paint, galvanizing, tin and enamel suffer very much under its action. A piece of rustless iron can be heated to redness, and then plunged into cold water without the least scaling or other change, so slight is the difference between the coefficients of expansion of the magnetic oxide and the metal.

Rustless iron is not affected by fresh water holding air in solution, nor by brines or alkaline solutions or sulphureted gases, and it withstands the action of salts in general, especially sulphate of copper.

Coated articles may therefore be exposed to sea water or to the most varied atmospheric conditions. Cast-iron receivers used for six months as urinals remained perfectly free from corrosion, while similar receptacles not protected by the oxide were strongly attacked.

Van Aubel, engineer of the Maestricht Royal Paper Factory, treated several articles, and then exposed them to the fumes of the laboratory without any deterioration.

Flamache, engineer of the Belgian State Railways, makes the following statements in a report on the Bower process:

1. Hydrochloric acid diluted to $\frac{1}{10}$ converts the magnetic oxide into sesquioxide which it dissolves, and into hydrated sesquioxide which scales off the surface, exposing the metal to the direct action of the acid.

2. A solution of caustic soda has no effect on the coating. If there is a crack in the coating, the exposed metal will rust as usual, but the rust will remain localized.

Though the adhesion of the Bower-Barff coating is considerable, it is not sufficient to permit of working and fitting iron in the same way as material that has not been treated. Rustless nails can be driven into wood and then withdrawn without injury to the coating. Coatings can be drilled without injuring the coating on the rim of the holes.

Flamache claims to have obtained the following results:

1. The rustless treatment does not alter the strength of the iron.
2. Under tensile or compressive strains the oxide adheres firmly to the iron until the limit of elasticity of the metal has been reached.
3. The oxide is chipped off the metal by a blow of the hammer; in riveting the coating to a distance of one centimetre around the rivet head scales off; and in shearing the coating scales along the edge of the metal.

According to these tests iron can be protected from rust when the articles are not to be submitted to subsequent mechanical treatment.

The magnetic coating can be reduced in thickness to a mere film, which will protect fine castings and polished ware from any but very energetic rusting action, producing at the same time a very artistic effect.

The first articles treated at the Hecla Works were suspended from the ceiling of the plating room, where they have been exposed above the vats to warm steam and acid fumes since the 20th

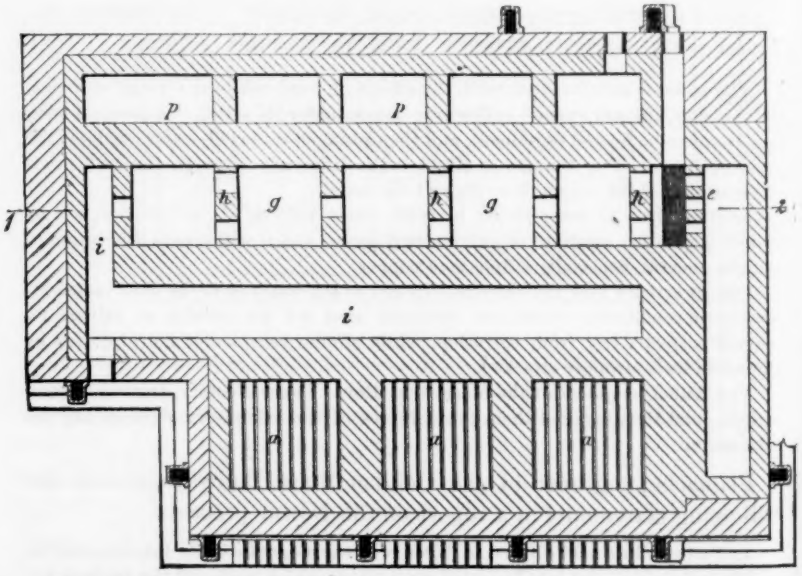


FIG. 4.—HORIZONTAL SECTION ALONG LINE 9—10 IN FIGS. 1, 2 AND 5.

of January last. They are absolutely unattacked, while plated and galvanized articles hung up at the same time were speedily red

with rust. Articles hung in the exhaust steam in the foundry yards were also unaffected.

I am indebted to my assistant, Mr. W. B. Kunhardt, for certain suggested improvements and for careful noting of results.

These improvements will be applied to furnaces now being constructed, and will also result in a considerable reduction in cost.

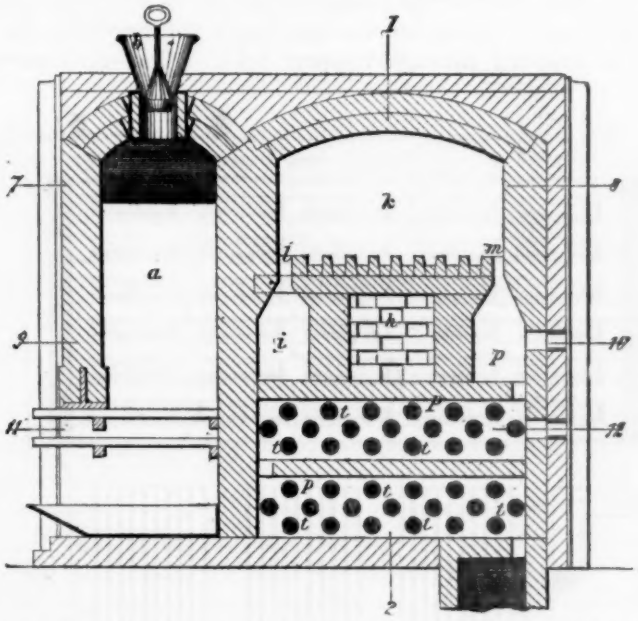


FIG. 5.—TRANSVERSE VERTICAL SECTION ALONG LINE 5—6 IN FIG. 3.

The accompanying cuts represent the English type of furnace which has been in continuous use for six months at the Hecla Iron Works in Brooklyn.

"The furnace is so constructed that the carbonic oxide from the generator being caused to meet with a current of hot air, combustion takes place, which is perfected before the products therefrom are admitted to the chamber containing the articles to be coated, and the waste products of combustion are caused to pass on their way to the chimney over and among a series of pipes, through which the cold air required for combustion is admitted, so as to become heated and prepared for admixture with the carbonic oxide. Continuous regeneration, therefore, takes place, and the operations are effectively performed under the most economical conditions.

In the following description the same letters of reference indicate corresponding parts in all the figures:

"Fig. 1 represents a longitudinal section of the furnace, taken along the line 1—2 in Figs. 2, 3, 4 and 6. Figs. 2 and 5 are transverse vertical sections of the same, taken respectively along the lines 3—4 and 5—6, Fig. 3; and Figs. 3, 4 and 6 are horizontal sections taken respectively along the lines 7—8, 9—10 and 11—12. Figs. 1, 2 and 5, *a a a*, are the producers for gasifying the fuel which is supplied through hoppers *b b b*. The carbonic oxide

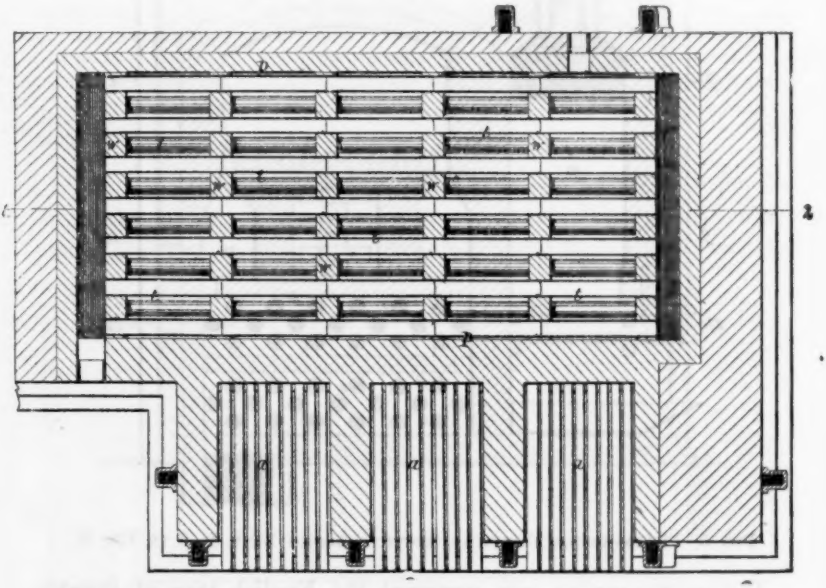


FIG. 6.—HORIZONTAL SECTION ALONG LINE 11—12 IN FIGS. 1, 2 AND 5.

from the combustion of the fuel in the producers *a a a* passes along a conduit, *d* (its flow being controlled by a slide, *c*), to the openings *e*, where this combustible gas meets a current of hot air ascending through a passage, *f*, and is consumed. The products of combustion are thence conducted along a passage, *g*, where they are thoroughly mixed by open brick-work cross walls, *h*, and then return along a passage, *i*, whence they enter, through the oblong holes *l*, the chamber *k*, in which the articles to be coated are arranged. After having passed over and among the articles to be coated, the waste escapes downward through ports *m*, into regenerator chambers *p*, and thence to the chimney flue *S*, heating in its passage the tubes

t composing the regenerator, and which are securely supported by the cross walls *W*. Cold air enters the apparatus at *v*, through a channel provided with a regulating valve under the control of the furnace tender. This air then passes along the lower rows of regenerator tubes and back through the upper tubes, thus becoming highly heated by the waste gases, and capable of developing greater heat when burned with the combustible gas."

DISCUSSION.

Mr. Henning.—What kind of fuel can you use to oxydize the material, or rather will large quantities of sulphur in the coal be injurious?

Mr. Maynard.—I am not able to answer that positively. I should assume, though, that it would be better not to have sulphur in the coal.

Mr. Henning.—I mention this particularly because in annealing steel bars we get as much as a sixteenth of an inch coating of sulphur on the bars, they being exposed about 30 hours to the gases coming up from the furnace from certain kinds of Pittsburgh coal, and I, of course, think that a very important matter in regard to this process.

Mr. Maynard.—I should presume it would be better to have coal free from sulphur; of course, we have not tested sulphury coal.

Mr. Oberlin Smith.—I would like to inquire the average thickness of the coating, and the maximum and minimum thickness of the coating in the various kinds of work on wrought and cast iron.

Mr. Maynard.—You can ascertain that by breaking off some of the coating here. If the things to be treated are to be exposed to any violent action, of course they want to be more thickly coated. I may as well say that with the exception of these polished samples, all of these samples have been lying in water a long time before they were brought here, and were then allowed to dry and were then wet again.

Mr. Le Van.—Why would it not be a good plan to coat boiler tubes by this process to prevent scaling?

Mr. Maynard.—We hope to have an opportunity of doing that, very soon.

Mr. Le Van.—For water tube boilers, that would be a great improvement, I should say.

Mr. Partridge.—Mr. President, in the paper which was read there was one statement made in regard to the endurance of this coating which, to those who are familiar with plumbing work, is more satisfactory and entirely conclusive than any other thing that could possibly have been suggested as a test. As I understood the statement, it was to the effect that a urinal had been coated by the process and been in constant use for six months without showing rust. Of all serious tests for rusting of cast iron or wrought iron, the urinal is the worst. No amount of painting, galvanizing lead-coating or enameling will protect an iron urinal. The acid seems to have a more destructive action on the iron than any other that iron is likely to come in contact with. And I should say that that was sufficient—if the coating will stand that, it will stand anything that it is likely to have elsewhere in the arts.

The President.—The chair would like to ask a question of Mr. Maynard: Have any tests been made concerning the use of this process for feed pipes, to overcome the destructive action of water of a certain temperature, which generally destroys wrought iron pipes especially?

Mr. Maynard.—No, sir; but we hope soon to have the pleasure of treating some pipes for our President, who wrote to me the other day on the subject. The difficulty was that our furnace was not long enough, but we are now putting up a larger furnace for the American Ship Building Company, so that we shall be able to treat pipes 22 feet long. Our policy has been up to the present time when inquiries have been sent to us, to have people send samples on, and let us treat them. There are lots of things we don't know about yet ourselves, and we should be very happy to treat anything, and then have it put to the most severe tests.

Mr. Hand.—I would like to ask if this process would not be valuable to treat the water end of pumps in coal mines? We had a statement last night of how destructive the acids contained in the water of coal mines is to the water cylinders of pumps.

The President.—I think Mr. Hand's question is a very pertinent one.

Mr. Maynard.—My answer is, that I should be very glad indeed to have it tested. Send us a pump and we will make the experiment. (Laughter).

Mr. Weston.—Did I understand that the coating would withstand the action of sulphate of copper?

Mr. Maynard.—Yes, sir.

Mr. Weston.—For any length of time?

Mr. Maynard.—These experiments that I have quoted are my authority. I have not yet had the opportunity of personally going into the matter in the detail that I would like.

Mr. Weston.—If it will withstand the action of sulphate of copper, of course it will stand the action of pretty strong sulphuric acid, because it will form a galvanic element there which would rapidly destroy the iron, and therefore I think it would meet the requirements of the gentleman behind who spoke about pumps, because in the mines you would have nothing to contend with but sulphuric acid; the other acids would not exist in the free state.

The President.—The Chair will remark in regard to his own experience that he desired the tubes from Prof. Maynard for some large heaters which we have. They are placed in flues, and consist of nearly 100 copper tubes, I think, about 700 feet long and two inches internal diameter. They were connected together by return bends and the water was pumped through the whole length of the heater, remaining a certain number of minutes (20 minutes or more), and it resulted in a very decided saving of fuel. But unfortunately the brass tubes of which the heater was composed lasted about a year, and then the sulphur in the coal attacked the brass and pitted it. After running about that length of time, the tubes began to burst. New tubes were inserted, but the casualties were so frequent that the firemen were alarmed, and we had to abandon the heaters, because it was considered that life was endangered. And we have remained until this time waiting to get hold of some material. We knew if we put in iron tubes that the feed water would very rapidly destroy them from the inside. We had no fear from any action of gases. And so these heaters, which cost us some $2,000 apiece, and the cost of which we could save very nearly in a year, have been obliged to lie idle until this process is ready for our use.

Mr. Root.—Mr. Chairman, I think the only thing you will find that will stand the action of acids upon flues or tubes is cast-iron. I have had some experience in that respect, and with wrought iron, I have known them to eat out inside of a month by putting cold water in them, where the water was so cold as to produce a sweat on the outside of the pipe; but cast-iron pipes seem to last very well. Now, there have been a good many Green economizers put in; I don't remember having heard of much trouble

with them. In those the pipes were made entirely of cast-iron, and I don't know that any of them ever gave out, although I have not had much experience with them. But I think there is one thing very certain; that you will find cast-iron will last better as a flue heater than any other material you can get. If the water is cold that is pumped through pipe, it seems to condense the acids from the products of the combustion on the outside of the pipes which will dissolve wrought iron in a very short time.

REULEAUX'S KINEMATIC MODELS.

BY

PROF J. BURKITT WEBB, OF CORNELL UNIVERSITY, ITHACA, N. Y.

In this paper Professor Webb explained the improvements made by Professor Reuleaux in the science of mechanism, and illustrated his remarks by a selection of models, copied from the celebrated collection of the Royal Polytechnic School at Berlin, and borrowed from the cabinets of Cornell University for this purpose.

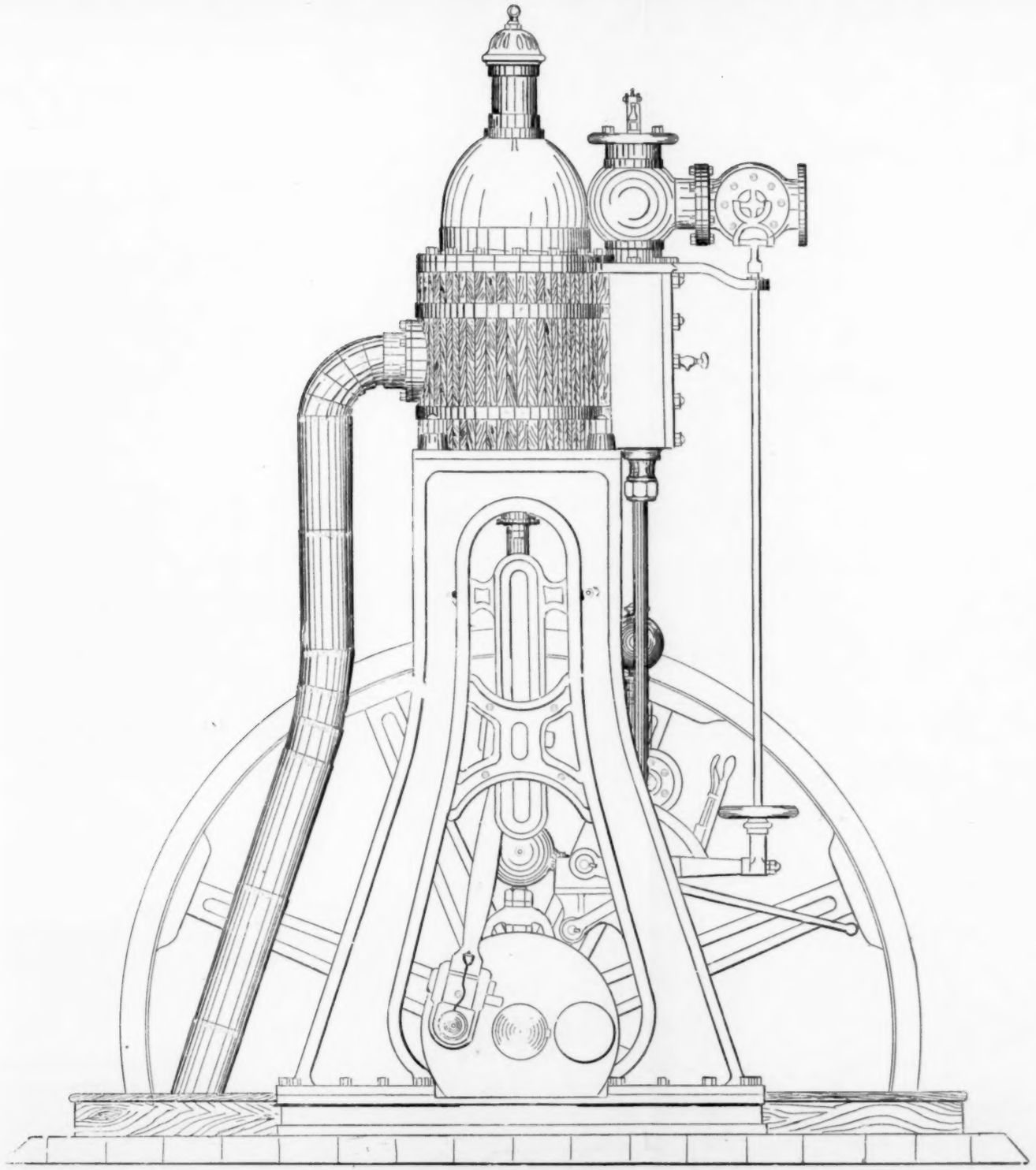
BALANCED VERTICAL ENGINES.

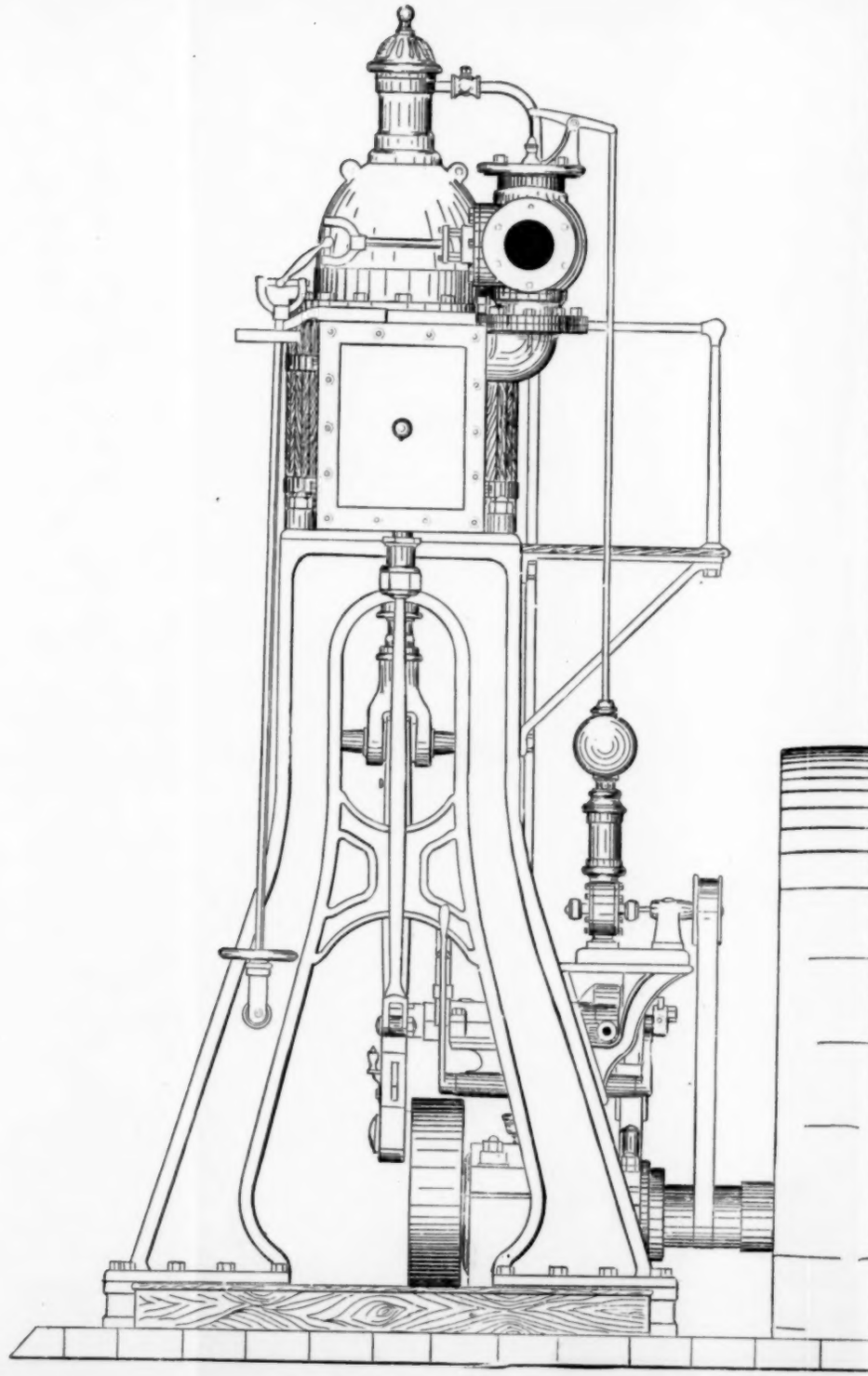
BY

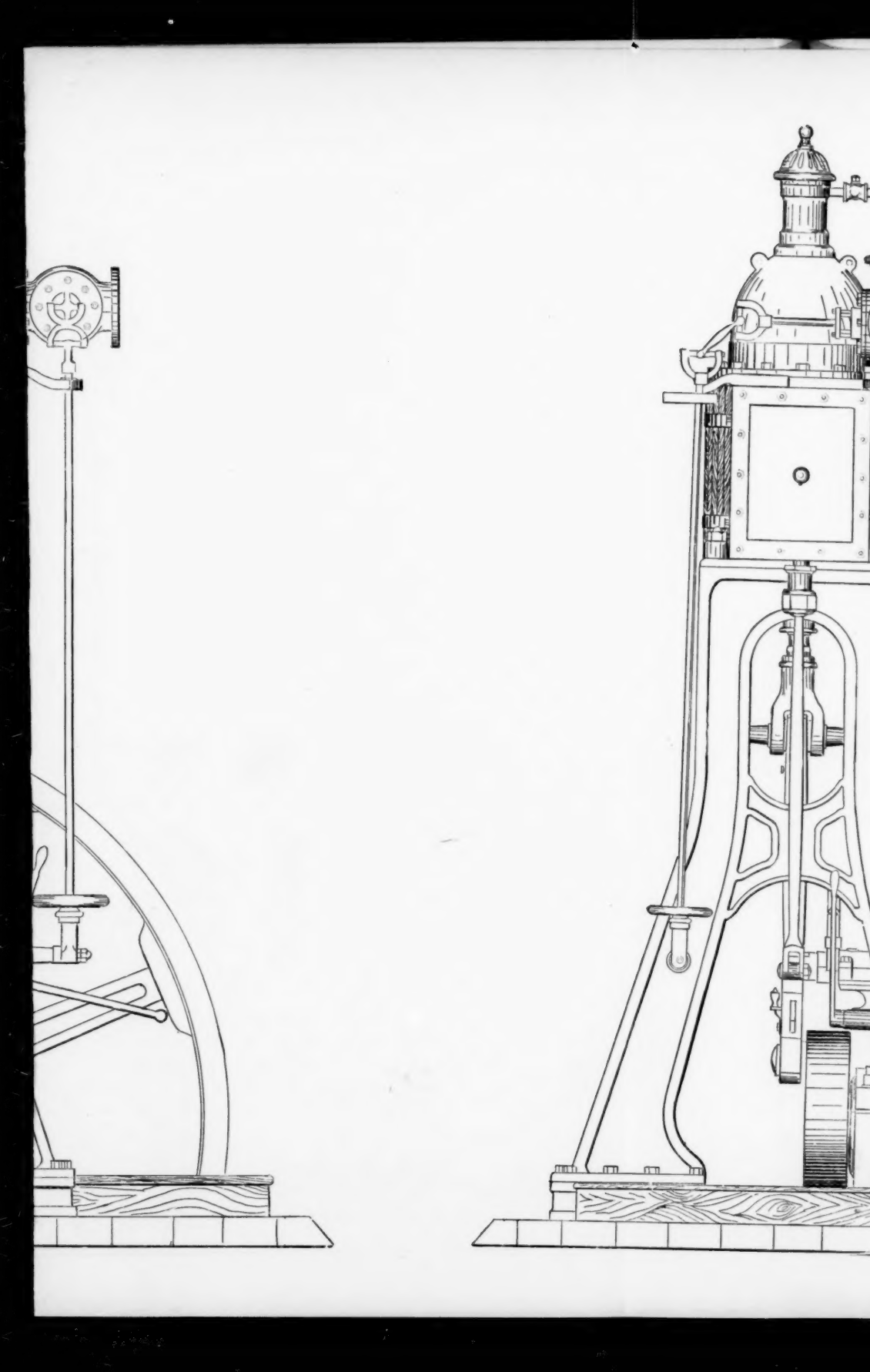
W. F. DURFEE, BRIDGEPORT, CONN.

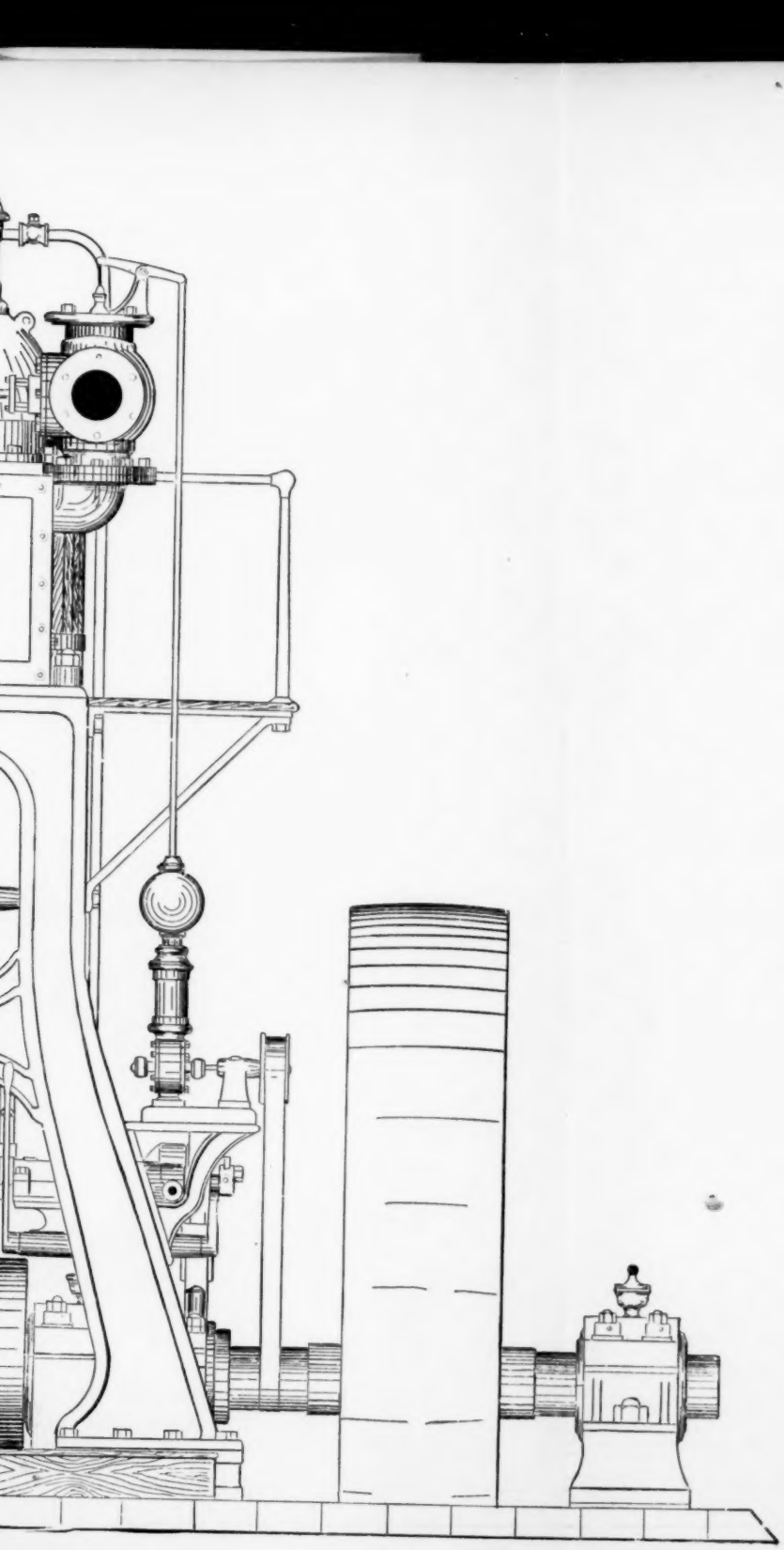
At the Altoona meeting of this Society, during the discussion of the paper of Prof. Robinson, there was a question asked relative to the possibility of balancing the moving parts of vertical direct acting engines, which failed to elicit a very satisfactory reply, the general impression being that it was a difficult problem, which might be, but never had been, satisfactorily solved by so arranging masses of metal that they moved in opposition to, and therefore balanced the reciprocating parts of the engine. It is the purpose of this paper to explain another method of balancing the reciprocating parts of direct acting vertical engines, for which the writer was granted Letters Patent, March 21, 1871, and which has been applied with success to engines designed by himself and others. The first engine to which the method of balancing about to be described was applied, was designed and erected by the writer in the years 1868–9, for driving a train of twelve-inch rolls in the works of the American Silver Steel Co., at Bridgeport, Conn., and I have selected the drawings of this engine to illustrate this paper, in which I will describe in addition to the peculiar method of balancing the moving parts, some other details of construction which I believe to be of value. The engine, as will be seen from the elevations, Fig. 1 and 2, is of the direct acting inverted cylinder type, and, in its general form and framework, presents no very conspicuous novelty, save that above the cylinder is seen what appears to be a dome surmounted by a cupola; to this feature I shall presently ask your more particular attention.

The diameter of cylinder and stroke of piston are each twenty (20) inches. The revolutions per minute when the train was run on small rods are two hundred and twenty-five (225), giving a piston speed of seven hundred and fifty (750) feet. The bed plate is six feet square and six inches in depth, and is strengthened by a number of ribs as shown in the drawing, Fig. 3. Before this plate is placed in position on the foundation it is turned on edge and filled with brick-work laid in cement mortar, and when this is suffi-









ciently dry to retain its place, the plate is turned down and leveled by a number of small pieces of iron in its final position, a space of

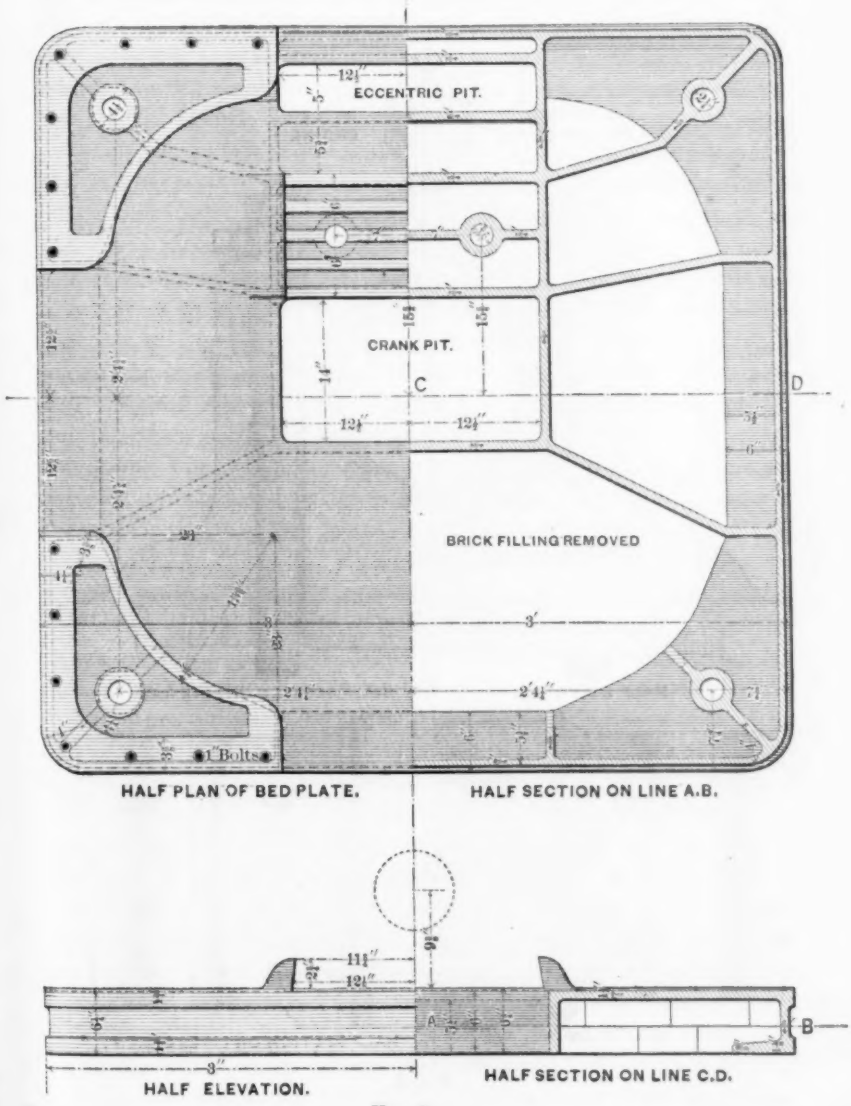


FIG. 3.

at least one-quarter of an inch being left between the under side of the brick-work in the bed-plate and the top of the foundation,

which space is run full of a strong cement grout as soon as the holding-down bolts are in place; thus insuring for the bed-plate a perfect bearing at every point of its area. The construction of the

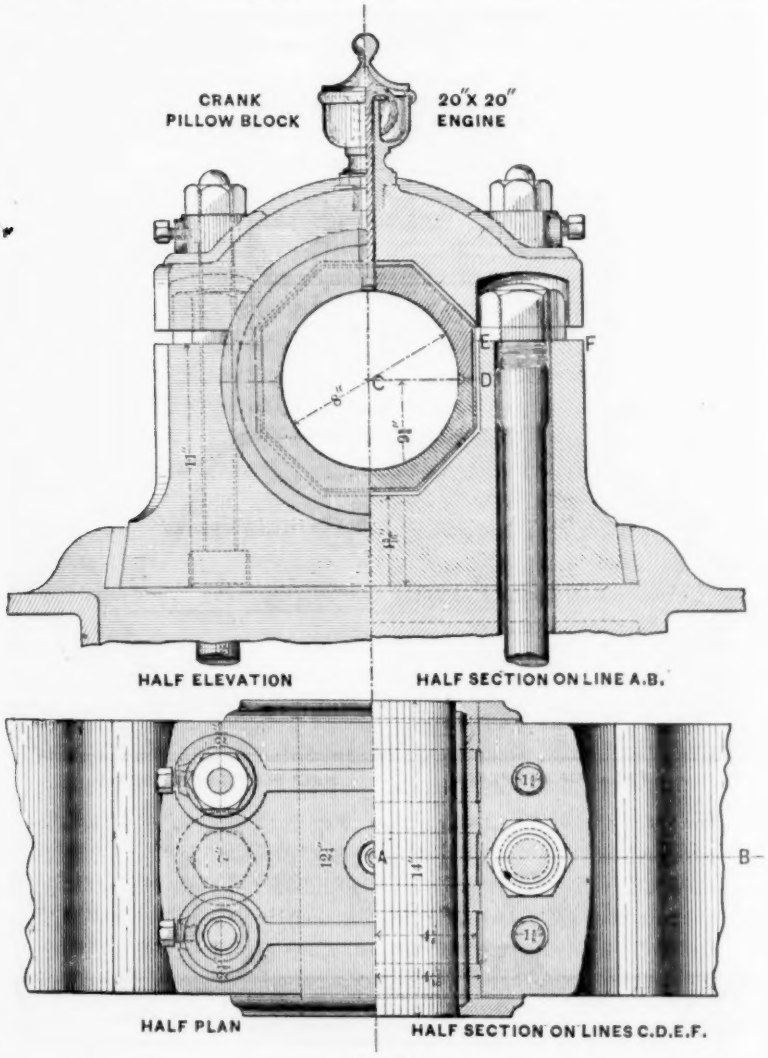


FIG. 4.

crank pillow-block presents some peculiarities; as will be seen in the drawing, Fig. 4, the pillow-block is held in position as against vertical displacement by two holding-down bolts, which pass

through its body in close proximity to the "brasses," the nuts of these bolts have a bearing upon the upper surface of the base of the pillow-block, and are covered by its cap; the block being secured against horizontal displacement by means of a key at each end. In this connection I will say that in some machinery which I have erected since the design of this engine, I have secured pillow-blocks against lateral displacement by running the space between the pillow-block and the key-lug full of Babbitt metal, and as the result of three years of experience of its use on a line of heavy shafting, I have no hesitation in recommending it as in every way satisfactory.

The frame of the engine has nothing especially novel in its details; it is composed of four similar castings fitted and bolted together, and provided with feet at their lower extremities, through which the holding-down bolts at the corners of the bed-plate pass, and they are also secured to the bed-plate independently of the holding-down bolts by a number of tap bolts, as will be seen in the elevations, Fig. 1 and 2. The four main castings of the frame are steadied and stiffened by four curved braces, which are fastened to them near the middle. The cross-head guides, which are simple rectangular troughs, in which the cross-head blocks slide, are secured to two of these braces as well as to the frame of the engine by turned and fitted bolts, the guides being planed in between vertical lugs on the inside of the braces, and all contact surface between guides and frame being also planed together.

To insure proper distance and parallelism between the under side of the feet and the top of the engine frame, after the frame and its braces were fitted together the whole was put in a lathe and the bottoms of the feet and the top of the frame were turned off. The steam cylinder is of the ordinary construction such as is in common use in the majority of tug engines; its bottom being cast solid with its body, save that a sufficient opening is left through its centre to accommodate the boring bar. This opening is closed by the stuffing box (figures 5 and 6), which presents one constructive feature which is believed to be novel, and which is certainly very satisfactory in its practical operation: I refer to the means by which the water which follows the piston rod through the stuffing box is trapped out and prevented from running over cross head and connecting rod. This is accomplished as follows: The stuffing box itself is made of greater length than usual and the packing is divided into two parts, separated by what may with propriety be

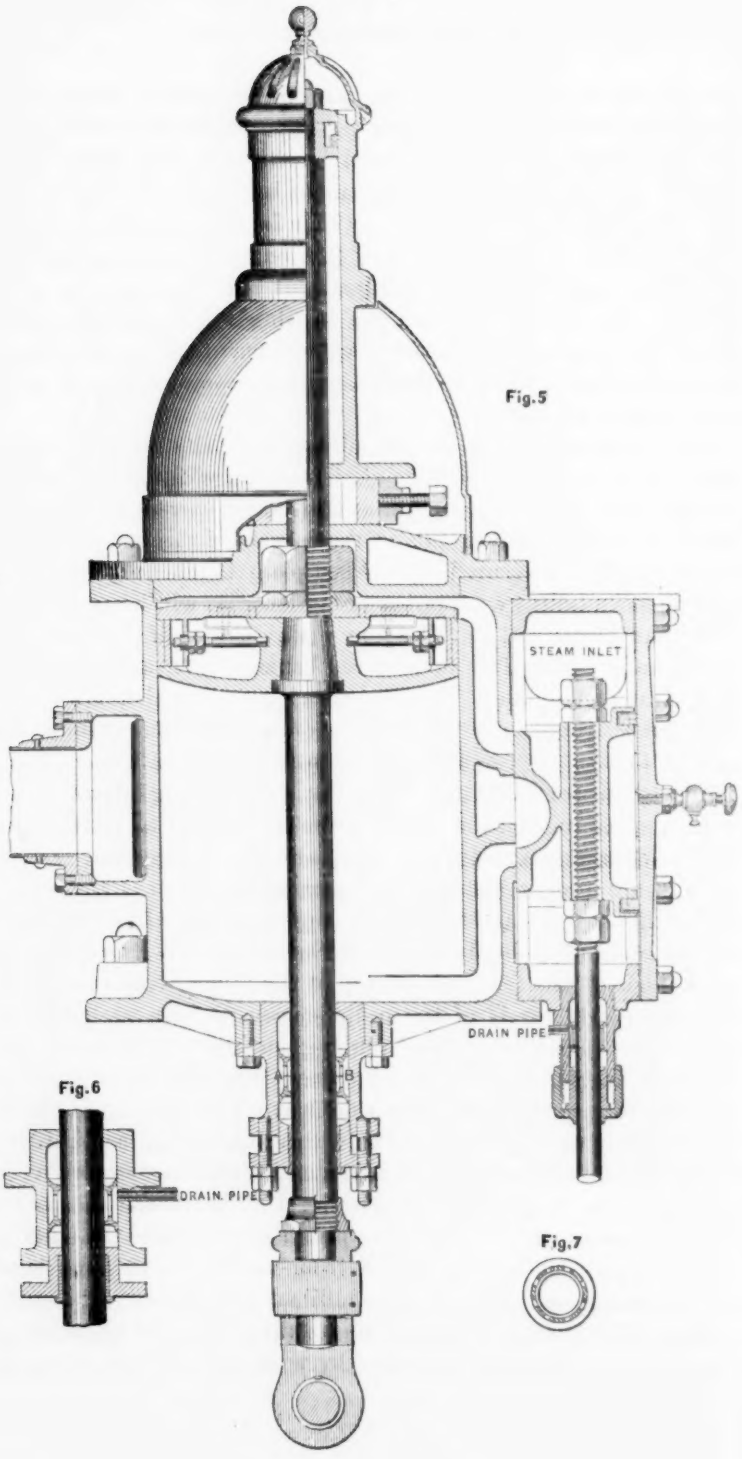


Fig.5

Fig.6

Fig.7

called a lantern gland, whose construction is plainly shown in the drawings, figures 5, 6, and 7. The larger part of the packing is placed above the lantern gland and the remainder below it, and the lantern gland, being free to slide along the rod as the gland proper is screwed up, communicates the pressure applied to the packing below it to the larger mass of packing above it. There is a drain pipe communicating with the hollow space of the lantern gland, for carrying off any water which is carried into it by the piston rod.

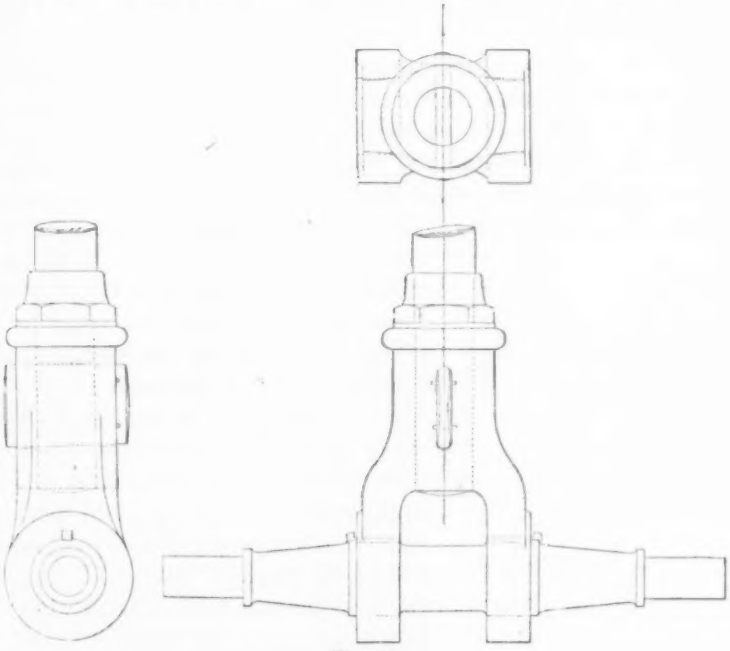


FIG. 13.

This drain pipe is so located relative to the lantern gland that, notwithstanding the latter's movement along the rod, it always remains in communication with the hollow spaces within it. The operation of this combination of parts is as follows: The water which follows the piston rod through the upper portion of the packing is received by the lantern gland from which the most of it passes off through the drain pipe, the portion of the water which is in that part of the lantern gland below the drain pipe being without pressure upon it does not find its way through the lower wart of the packing but remains in the gland and acts as a lubricant to the piston rod. The details of the cross head presents some constructive novelties; the

cross head block is a forked forging of wrought iron, which, instead of being bored "taper" for the reception of the conical end of the piston rod, is bored cylindrical, and the end of the rod is turned to fit it, and in order to preserve all the strength possible and provide a proper shoulder for the piston rod, a fine screw thread is cut upon it just above the cross head block on which is run a gun metal nut (as is shown in figure 5), which receives the downward thrust of the rod, its upward pull being sustained by a steel key passing through the cross head block and piston rod below the nut. This construction admits of a larger cross section of solid metal in the piston rod adjacent to the lower edge of the key than is usually given, and at the same time simplifies the workmanship required. The fork of the cross head block is bored at right angles to the piston rod, and through it is passed the cross head pin secured against rotation by two small keys: the extremities of this pin are turned cylindrical and are fitted, but not fastened, in cylindrical holes in the slide blocks; these are provided with "brasses," the working brass being adjusted for wear by a wedge bolt and nut, the wedge being pinched by a side set screw; both the working brass and its fellow are precisely alike, and when the working brass is nearly worn out it can be shifted to the other side of the slide block, a "liner" of proper thickness being made to take the place of that which secured the unworn brass in place: this "liner," as will be seen in the drawing, is planed into both the brass and the body of the slide block, and is prevented from dropping out by a small transverse pin, by removing which both liner and brass can readily be displaced without disturbing the body of the slide block, and the working brass can also be easily removed by unscrewing the adjusting nut on the wedge bolt and letting the wedge drop through the bottom of the brass. The lower ends of the "brasses" are provided with inclined holes, which, as these ends dip at every stroke of the engine into the oil cup at the bottom of the guides, carry up oil enough for their lubrication.

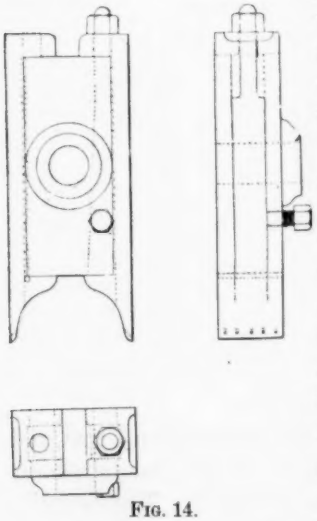


FIG. 14.

The pressure of the steam upon the back of the slide valve is

partially removed by an automatically packed balance ring, the invention of William B. Robinson who patented it in 1864, he being at the time the mechanical engineer of the firm of Jackson & Wiley of Detroit, Michigan. Speaking from my own experience in the use of this invention on a large number of engines, I will say

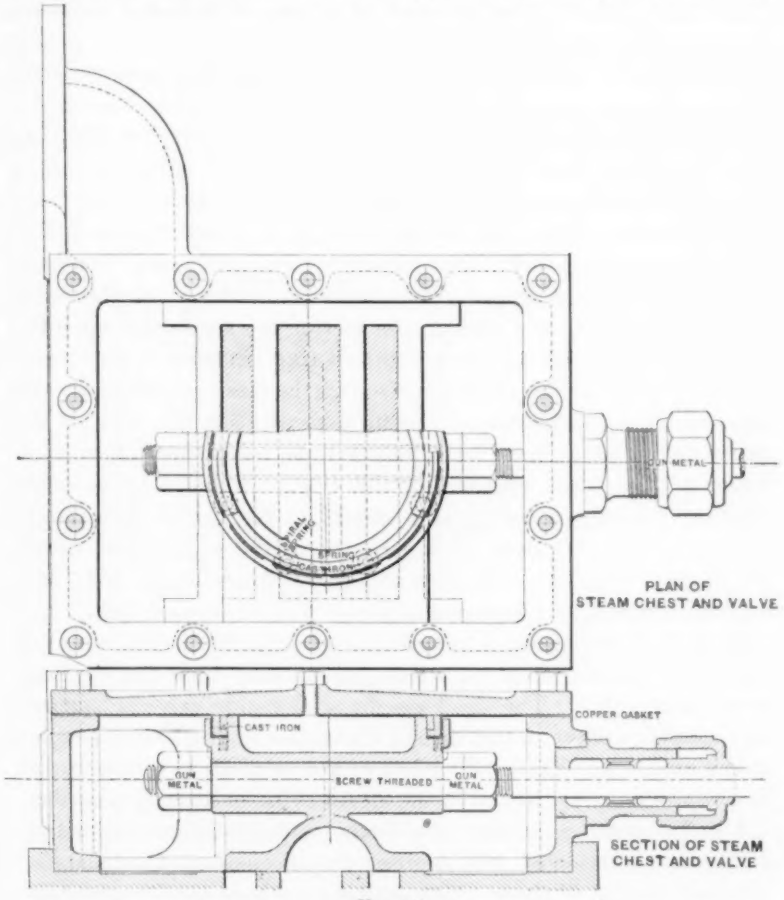


FIG. 12.

that it deserves to be much more widely known and generally used than it has hitherto been;—it does not pretend to be a perfect balance, that is, to relieve the valve of all the pressure upon it, but by its use the objectionable steam pressure is very materially reduced. In fact, in my own practice I have found it convenient so to proportion the balance ring, that sixty per cent. of the pressure of steam was removed from the back of the valve when both steam

ports were closed. The construction of this balance ring is very simple;—the steam chest cover is planed off on its under side, but the body of the slide valve does not quite touch this surface. On the back of the valve is a circular groove which is truly turned; in this groove is placed a compound ring made of cast-iron. This ring consists of an outer member of L section inclosing an inner member of rectangular section, as is plainly shown in the section of the valve in Fig. 5. The two members of the compound ring are cut transversely into the same number of segments and are so located with respect to each other as to break joints (see Fig. 12). This compound ring is supported by a number of spiral springs of brass wire which are strong enough to sustain the weight of the ring in contact with, but without exerting of themselves an undue pressure upon the steam chest cover, their object being simply to keep the ring from dropping away from the cover when the steam is shut off. When the engine is in motion the steam acts upon the under and outer side of this compound ring pressing it into steam tight contact with the planed surface of the steam chest cover, and the smaller circumference of the turned groove in the back of the valve within which the ring is placed, thus preventing all access of steam to the space inclosed by the ring. In order to ascertain whether the ring is acting as it should, it has been my custom to put a common try cock in the centre of the steam chest cover, which cock is always left open and any leakage of the ring is at once manifested by the escape of steam from this open cock.

In case of any undue accumulation of water in the cylinder the valve will leave its seat with even greater ease than the ordinary unbalanced valve. The dead weight of the slide valve is balanced by a counter weight on that arm of the rocker shaft which is coupled to the excentric. The stuffing box of the valve stem is constructed in a similiar manner to that of the steam cylinder already described.

I will now call your attention to the most prominent peculiarity of the construction of this engine; the mechanism for balancing the dead weight of those reciprocating parts connected to the main piston. The piston rod is secured to the piston by two gun metal nuts, the rod where it passes through the piston being enlarged as shown in the drawings; above these nuts the piston rod is prolonged of the same diameter as it is below the piston, and passes through a stuffing box in the upper cover of the cylinder and then enters a small cylinder in which it has attached to its upper extremity a small piston. The stuffing box just named is of a very

old and also of a very uncommon construction ; the only instances in which I have seen it employed are in machinery of my own design, and I know of but one work, and that was published thirty years ago, in which it was ever illustrated; and I will say before describing it that I have found it to work very satisfactorily in practice.

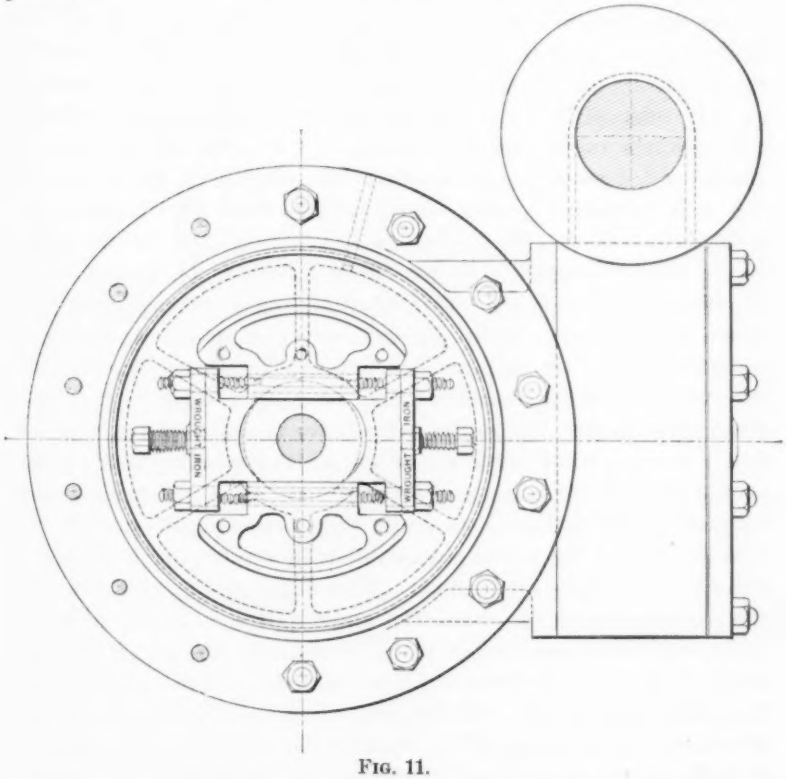


Fig. 11.

The space intervening between the upper cover of the main cylinder and the lower end of the small cylinder resting upon it in the immediate vicinity of the piston rod is occupied by this peculiar stuffing box, which may be described as a channel having parallel planed sides with open ends, the bottom of the channel being formed by the top of the cylinder cover, and its top by the bottom end of the balance cylinder. The otherwise open ends of this rectangular channel are closed by two gland blocks, which are made to compress the packing around the rod sideways, by means of set screws acting against their centres, said screws passing through

wrought iron plates whose ends are united by two equalizing bolts as is show in drawing (Fig. 11). By means of these bolts it will readily be seen that all strain upon the piston rod tending to force it laterally is avoided while at the same time the packing is effectively compressed. The small piston to which the upper end of the piston rod is attached is so proportioned that when steam of boiler pressure acts upon its under surface the upward pull due thereto is sufficient to balance the dead weight of all the vertical reciprocating parts. Steam is supplied to this cylinder through an $1\frac{1}{4}$ inch pipe connected to the main steam-pipe between the throttle valve and the boilers. The cylinder is therefore always filled with steam whether the engine is in motion or not, unless indeed a stop valve in the small pipe usually open is closed. When the engine is in motion the steam passes freely into the small cylinder below its piston on the up-stroke of the engine and out of it into the main steam-pipe on the down stroke, there being no loss save that which results from radiation. The air and dust is prevented from entering the balance cylinder on the descent of the piston, by closing its top by a brass dome casting, but as the space above the small piston will certainly become filled with air or steam, and possibly some water, should the engine remain standing for some time, provision is made for getting rid of these by a drain pipe communicating with the channel around the top of the cylinder, in which pipe is placed a "check valve" opening outward. Thus at the first upward stroke of the engine everything above the small piston is expelled, which action will of course leave a partial vacuum in the small cylinder above its piston on its down stroke:—advantage of this fact is taken in determining the size of the balance cylinder, and by making proper allowance for the value of the vacuum the area of its cross section is made smaller than would otherwise be advisable. The engine whose leading details I have described to you, ran absolutely silent, with no vibration in its frame, and with an easy buoyant movement of its reciprocating parts that excited the surprise of all who saw it; it was handled easy by hand and did not annoy its engineer by showers of scalding water from its stuffing boxes.

I regard a well designed inverted direct acting engine as in every way preferable for most purposes to any form of horizontal engine for the following reasons:

1st. It has much less frictional resistance.

2d. It occupied much less floor space. This, in the case of engines

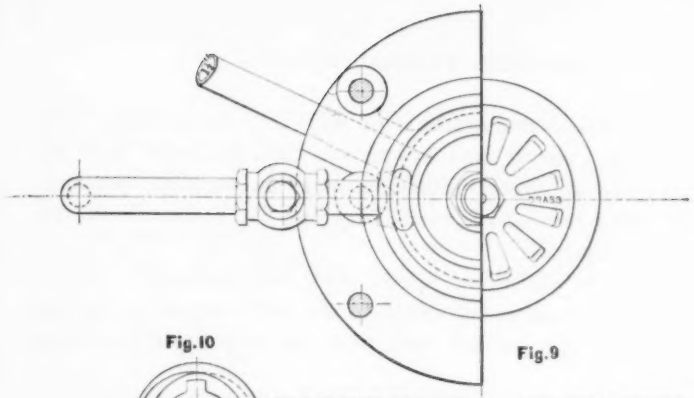


Fig.10

Fig.9

HALF PLAN OF CYLINDER

HALF PLAN OF COVER

PLAN OF PISTON

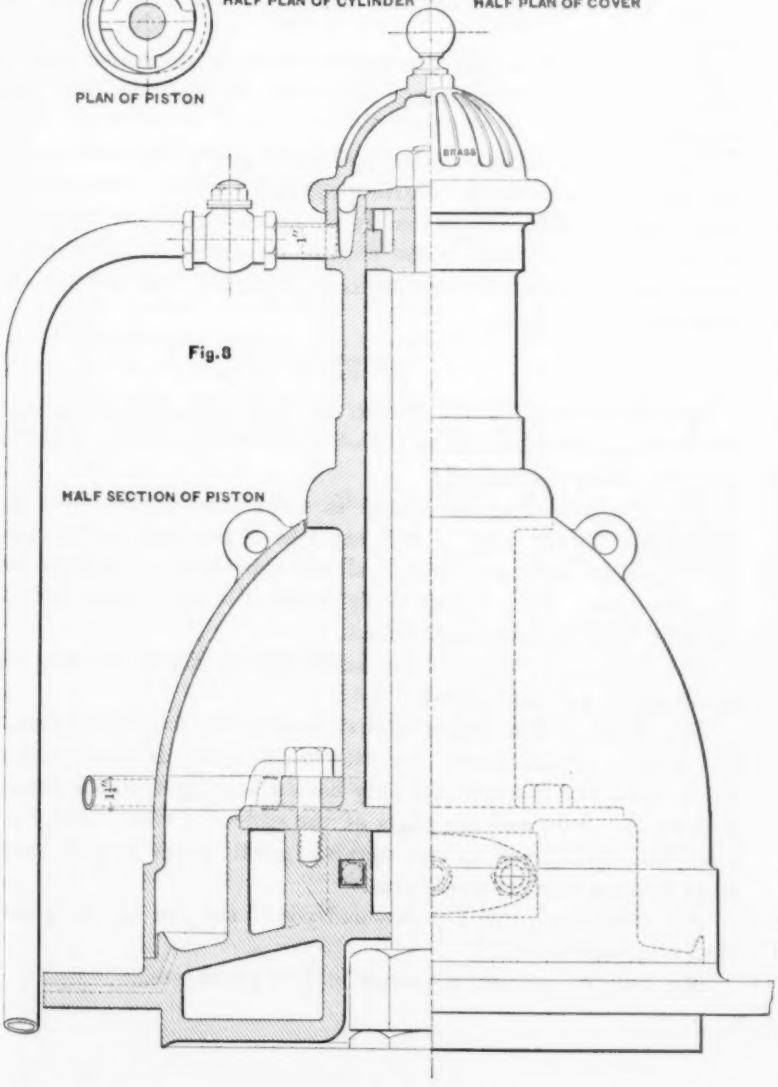


Fig.8

HALF SECTION OF PISTON

in larger cities where real estate is of daily increasing value, is no small advantage; electricians appreciate this, and now that the electric light has apparently come among us to stay, compactness in the arrangement of machinery for its production is regarded as very desirable.

3d. It is capable of higher speed than the horizontal engine. This feature will commend itself to all who regard power as mainly consisting of space and time, with but very slight seasoning of pressure.

4th. The foundations required are much less both in mass and cost.

5th. A vertical engine can be erected in a contracted position difficult of access with greater ease than any form of horizontal engine.

I do not wish it to be understood that I prefer the slide valve to all other forms of steam distributing mechanism. Any form of valve gear desirable can as readily be applied to a vertical engine as to a horizontal, and in the engine illustrated I used the slide valve because under the conditions existing I thought it the best adapted to meet them.

DISCUSSION.

Mr. Henning.—I would like to ask what advantage it is to put the holding-down bolts in the block so that you cannot get at them without taking the cap off?

Mr. Durfee.—The advantage is compactness, cheapness, and neatness in every way. I will say I have not had one of those holding-down bolts get loose in all my experience. Perhaps they do sometimes. Still, if they do get loose, it is very easy to get that cap off; it takes but a short time.

Mr. Henning.—What is the advantage of filling the base with brick before you set it down?

Mr. Durfee.—The object of that is to insure the distribution of the weight of the frame over the whole area. If there was no brick work, the frame would only have a bearing upon the foundation on the sides, and the edges of the stiffening ribs; but by putting that brick work in and running grout under it you have a solid bearing over its whole area.

Mr. Henning.—Did I understand you to say you put one-quarter inch of grout under it?

Mr. Durfee.—About a quarter-inch of grout, yes.

Mr. Henning.—Will you please tell me how you get it in, unless you make it very thin?

Mr. Durfee.—It does not require to be very thin; you can push it in with a rod from all sides until it comes out in the crank bed, which goes over the whole frame, and it is very easily calked in.

Mr. Henning.—Did you say your bed-plate was about six feet square, with a quarter of an inch of space between it and the foundation?

Mr. Durfee.—Yes.

Mr. Henning.—And you get a good grout in there?

Mr. Durfee.—Yes. In some places there might be three-eighths of an inch; if it was half an inch it would not matter. I am speaking of the principle more than the precise thickness.

Mr. Henning.—I attempted the same thing in several hundred cases with beds about 28 inches square—varying from 28 to 32 inches square—and it was not successful. I could fill it with a very weak grout, but by using a good grout, which kept the superstructure where I had it, I could not do it at all.

Mr. Durfee.—I will say in reply, that in my own experience I have not only been successful in the engines I have put up myself—I have had three of them put up under my own supervision, and I have also put up very heavy castings—in one case they were four feet square with no hole in them, and ran the grout in from one side with a dam of clay around; and it worked entirely satisfactorily.

Mr. Henning.—Another question. You have remarked that a vertical engine can be made to run at a higher speed than a horizontal engine. Will you please state the reason why that is so?

Mr. Durfee.—I state it as the result of my thought and experience in connection with the subject. I think there is every reason why an engine balanced in that way should run faster than by any possibility you can make a horizontal engine run.

Mr. Henning.—Is there a vertical engine running to-day which runs as fast as high speed horizontal engines?

Mr. Durfee.—I cannot say, sir. I do not know how fast the high speed horizontal engine runs, but I should not be afraid to run that engine a thousand feet a minute.

Mr. Henning.—I had never heard of a vertical engine that ran at as high a speed as the Porter-Allen, or the Buckeye engine.

Mr. Durfee.—At how high a speed do they run?

Mr. Henning.—I forget the exact number of feet of piston speed. Mr. Leavitt probably could give us better information on that.

The President.—They run up as high as nine hundred feet; that is the highest I have ever known.

Mr. Durfee.—This engine ran without a particle of vibration. When there was no noise from the machinery adjacent to the engine, you could stand and put your hand on the frame of that engine and you could not tell whether it was running or not. It was running seven hundred and fifty feet a minute. I should not hesitate to run an engine of that size a thousand feet a minute.

Mr. Scott.—Mr. Chairman, I would state in connection with this matter of grouting bed-plates that I have had considerable experience, not only in putting down foundations for engines, but under machinery of a very heavy class, such as is used in the manufacture of gunpowder, where we have a bed-plate from eight to nine feet in diameter, on which move heavy masses of cast-iron in the shape of rollers. We have a shifting weight of from eight to ten tons on each side, and those shifting weights are much more difficult to maintain a foundation under, than the ordinary engine. We always put those down in grout by building an ordinary stone foundation, and the bed-plates have a central hole in them, and where we make bed-plates under the engine we very often make the foundation with a large stone or with a cope-plate. We have holes through the bed-plates or cope-plates, and we use the ordinary foundryman's trick of forcing that grout in by putting in a stand pipe, through which the cement is introduced. I have grouted cope-plates on the top of a pier for setting a Corliss engine, where I have driven it over a surface seven or eight feet in width by as much as thirty feet in length, having a quarter-inch space between the plate and the masonry. You can make that grout of any consistency you please, and even quite thick. (Applause.) I have sometimes put up a stand-pipe as high as eight or nine feet, and I can lift the bed-plate or force the cement through the smallest opening by the hydrostatic pressure. It is merely a matter of building the pipe up to a sufficient height.

Mr. Henning.—That covers my point exactly. I can get the grout in and make a good bed by putting it in under pressure.

Mr. Scott.—We do that thing when there is no opening through the plate, by just putting a stick of timber on the outside of the frame with a rabbit under it. That makes a channel around the

entire frame. Weight that with stone and put up a pipe or four pipes, one on each corner. I have done that.

Mr. Hewitt.—In regard to the speed at which horizontal engines can be run, I can state that the Trenton Iron Co. have a horizontal Corliss engine 20 × 42, making 160 revolutions per minute, or a piston speed of about 1,100 feet. This engine has been in constant use running at this speed for about seven years, has required but very few repairs, and is still in fair condition. A description of the engine will be found in a paper on "The Continuous Rod Mill of the Trenton Iron Co.," which I had the pleasure of reading before this society at the meeting in Hartford.

Prof. Webb.—Mr. Chairman, I would like to ask the question, whether the vibration of an engine depends directly on the piston speed. The piston speed alone has been spoken of in two or three remarks. Now, does it depend upon the piston speed alone? That is, will two engines having the same piston speed necessarily vibrate the same or require the same stability in order to keep them from vibrating?

Mr. Le Van.—I think it does not depend on the piston speed as much as on the number of revolutions the engine makes. I had a small engine in my shop that ran 300 revolutions a minute for about ten years, and had no trouble at all with it. The change of motion affects the foundation; it is not the piston speed.

Mr. Webb.—I think, Mr. Chairman, it would depend on the piston speed *and* the number of revolutions, as far as it depends on either of them. If two engines have the same piston speed and one has double the number of revolutions that the other has, then the accelerating force will be twice as much in the former case as in the latter. The piston of one engine will come to its maximum speed in half the time occupied by the other in reaching the same maximum, and in doing so it will move over only half the space, therefore, the force required will be doubled. This is about the state of the case when the engine is running with steam turned off; but if the steam pressure used is the same on both pistons, then I should say that with steam on there would be but little difference in the steadiness of the two engines, except for one fact. The main reason why an engine properly set up will sometimes vibrate is that it often finds the foundation, etc., ready to vibrate in unison with it, and this is more apt to be the case when the time of vibration is short, and such rapid vibrations are more noticeable. If an engine be properly constructed in itself and

properly set up, I do not see that serious vibrations are any more to be feared in a quick than in a slow running engine.

The President.—It would seem to be a question of the weight of the parts and the stability with which they were held down. I suppose that if we had a cylinder of 20 inches and we had mass enough to attach to it, it could be run absolutely without vibration, even if the parts were not balanced; but probably it would be destructive on the parts after a while.

In regard to the speed of vertical engines, if I remember correctly, I saw an engine run a thousand revolutions a minute at the Delamater Iron Works, but Mr. Miller can tell me if I am right about that.

Mr. Miller.—Yes, sir; it is a vertical engine driving a dynamo, and has been running during the past two winters about four hours per day, developing ten horse power and making 1,250 revolutions per minute.

Mr. Comly.—Will the gentleman please be so kind as to mention the stroke of the engine?

Mr. Miller.—It has rather a short stroke, only three inches.

Mr. Comly.—That would, of course, make considerable difference.

Mr. Hamilton.—I would like to ask the gentleman whether he had any trouble in regard to the balance valve floating up. I have had some experience with that kind of balance slide valve, and I found that if the valve was adjusted so as to use the necessary compression for a quick-running engine, the valve would float up, allowing steam to blow through. I have been compelled to reduce the compression until the valve would keep its seat.

Mr. Durfee.—That is a question of the proportion of the ring to the area of the valve. If you get that ring too big, you can do that—I have no doubt about it. But in this case I have had no difficulty with it at all.

Mr. Baldwin.—I would like to ask what effect the changes in initial pressure would have on that piston?

Mr. Durfee.—The changes that occur in boiler pressure in the case of engines that were run under my own supervision were so slight that there was no apparent effect on the engine. The boiler pressure was kept within a few pounds. The engine is calculated for a particular pressure. You would have to know what your boiler pressure was when you built your engine, or adapt the boiler pressure to the engine.

Mr. Thomas R. Morgan, Sr.—Mr. President, does it not seem

reasonable, in comparing the vertical with the horizontal engine, to consider the weight of the piston and its connecting parts? Would they not have a tendency to be very hard on the vertical engine, in comparison with the horizontal? That weight is taken off in the horizontal engine, while the vertical engine generally has it. There is hardly any way of balancing by which you will not have that dead weight downward. That certainly must be very hard on the down stroke. That you do not have to contend with at all in the horizontal engine. It seems to me that is very largely in favor of the horizontal engine in high speed.

Mr. Durfee. I will say in reply to that objection that that was the very reason that balance piston was put on. By putting the balance cylinder on you annihilate the dead weight. That balance cylinder sustains all that dead weight. The piston practically weighs nothing.

Mr. E. Comly.—May I ask if that arrangement of balancing the piston is not the same as is used in balancing the valve stem and valve gear on large marine engines?

Mr. Durfee.—I will say that that principle is precisely the same, and that the balancing of valves in that way has come in use since this patent was issued. This was before the time that any valves were balanced in that way.

The President.—The Chair would remark from personal observation that any well-built engine of any type, whether vertical or horizontal, can be made within reasonable limits to run satisfactorily smoothly, and though in his own practice he has preferred to have the cylinders of large engines vertical, the practice of other people for whom he entertains great respect has been to build horizontal engines; and we shall see to-morrow at the Otis Steel Company's a forty-inch horizontal engine, which I think will please every one of us. It is simply a matter of properly balancing the parts, making the static parts of the machine heavy enough, and in addition to that making about four times as much foundation as seems to be necessary. (Applause and laughter.)

Mr. Durfee.—Mr. President, I think your remarks are a very strong argument in favor of the vertical engine. (Laughter.) We get in it a minimum foundation and a minimum friction. In these quick working horizontal engines the piston is traveling over the length of the cylinder very frequently, and I have known some of them, after a very few years' run, suffer very seriously on account of the friction of the piston.

Mr. Sweet.—Mr. President and gentlemen, I believe it is not usual to continue the discussion after the President has made his final remarks, but as others have spoken I would like to say a few words.

We have an engine which we can balance very readily, with fly-wheels each side and close to the crank. We can put the counter weight where we please. I had accepted Mr. Porter's mathematical conclusions as correct [he has always been my patron saint on steam engineering] (laughter), and put enough weight in the fly-wheels exactly to counterbalance all the reciprocating parts. Our partners in Chicago have not been satisfied with the running of the engines, and have been experimenting. They took two engines and balanced them, on the plan we were following, then took weights and added to the fly-wheels, shifted them from one place to another, increased and diminished the weight, until they got the engines so they say they run better than any engine we have ever built.

Now, the remarkable thing is that in an engine 8x14 in size, running 250, balanced as we balance them, they put in 35 pounds of metal in the rim of the fly-wheel, which has a radius four or five times the length of the crank—35 pounds of metal, and that on an engine where the reciprocating parts weighed about 195 pounds. And what is more strange, the weight is not opposite the crank; nor is it on the crank side; neither is it 90 degrees from the crank, but, as nearly as I can judge, 15 degrees back of the crank. These engines run, they say, perfectly quiet, not only on a solid foundation, but on an unstable foundation. They propose to continue these experiments on every engine and keep a record of them, and we propose to do the same thing independently; if we arrive at the same conclusions, we think we will have settled something that will be of value about balancing an engine.

Mr. Scott.—Mr. President, I wish to indorse one remark made by you in regard to the foundation of engines. There is one method of making a cheap foundation that is not understood, perhaps, as well as it should be. I will mention an experience I had in setting one engine. It was a horizontal engine, about 14 inch cylinder. It was put down on ground that was a little soft. We dug down some eight or ten feet, and we had a fairly good foundation. Then we piled it the best we could, and we put in the ordinary stone structure, set the engine and started it, and we found the ground was so soft we could feel the vibration of that engine

outside of the building where it was placed and 30 or 40 feet away from the foundation pier, and we were in a fix. We did not have time to take it up, and would not have known what to do if we had taken it up; but as an experiment I excavated a trench which was an extension of the foundation of the engine, lengthwise, for a distance of about 60 feet, and I filled that trench with firm material and rammed it down. I filled in about half of it first, and we started the engine. We found the vibration nearly ceased. Then I extended it about 30 feet farther and rammed that trench full, and we killed the vibration, and since that I have adopted the old farmer's method of digging a post hole and setting a post, by filling it with material and ramming it down, and I have found that answers as well as stone in a great many cases.

BÉTON IN COMBINATION WITH IRON AS A BUILDING MATERIAL.

BY

W. E. WARD, PORT CHESTER, N. Y.

If society is indebted to the restless spirit of progress for most of its modern comforts and conveniences, it certainly is not yet a debtor for any methods which guarantee immunity against calamities from fire. While other departments of industry have received the benefits of improvement, the continuous and persistent use of combustible material for exposed portions of buildings has limited the intrinsic elements of the art of building construction, and confined improvements only to matters of design.

Incombustible materials are easily obtained and much better adapted to the purpose for every apparent reason. Doubtless the question of increased cost, both in money and in time, required for more thorough construction may be in a measure responsible for the tardiness in adopting safer methods, and, in addition to greater expenditure, there may have been a want of confidence in the fire-proof methods which have been offered to the public for adoption. The importance of this question induced the writer, in 1871 and 1872, to make some experiments in a new and special direction, for the purpose of ascertaining whether a practically fire-proof building could be designed and constructed at a comparatively moderate cost.

The incident which led the writer to the invention of iron with béton occurred in England in 1867, when his attention was called to the difficulties of some laborers on a quay trying to remove cement from their tools. The adhesion of the cement to the iron was so firm that the cleavage generally appeared in the cement rather than between the cement and the iron.

The line of experiments which followed were confined exclusively to working up the reciprocal value of béton, in combination with iron, in the construction of beams which were designed for supporting floors and roofs made of the same material. In this particular, the facts were conclusively developed, beyond question, that the utility of both iron and béton could be greatly increased

for building purposes, through a properly adjusted combination of their special physical qualities, and very much greater efficiency be reached through their combination than could possibly be realized by the exclusive use of either material separately, in the same or in equal quantity.

Experience had long ago proved that unprotected iron, associated with combustible materials, is altogether unreliable for building purposes when exposed to a severe fire test; but it has been demonstrated that if iron is well protected by a heavy clothing of béton, its integrity can be safely depended upon under almost any emergency.

When all doubts were removed concerning the reliability of the several combinations of materials required in the construction, a building embracing the following radical new features was erected, for dwelling purposes, near Port Chester, N. Y. Not only the external and internal walls, cornices and towers of the building were constructed of béton, but all of the beams, floors and roofs were exclusively made of béton, re-enforced with light iron beams and rods.

Furthermore, all the closets, stairs, balconies and porticoes, with their supporting columns, were molded from the same material. The only wood in the whole structure was in window-sashes and doors with their frames, mop-boards and the stair-rails; thus excluding everything of a combustible nature from the main construction.

Béton can be used in any form of construction, and is able to serve the requirements of any architectural or decorative effects. All the exterior portions of this house, which are more or less ornamental in their functions, were made of béton in place during the progress of the work. In the interior of the house, the cornices, stiles, and panels of the ceiling are formed of béton, and covered with the hard finish usual in such work. There appears to be no limit to the reproduction in béton of any form used in stone masonry or in stucco. The proportions of material composing the béton for the work varied in strength to meet the requirements of the different parts of the structure, the heavy walls needing the least proportion of cement, while the beams, floors and roofs required a much larger proportion. Only the best quality of Portland cement, clean beach sand, and crushed bluestone were used in combination with iron for constructing the building.

The proportions of cement used for the heavy wall work were one part of cement to four parts of sand and fine gravel, thoroughly mixed dry, and dampened with only sufficient water to give it the consistency of well-tempered molding sand.

A finely crushed and screened hard blue limestone was found

VIEW OF THE HOUSE.

to be better adapted for use in combination with the béton than a coarse-sized stone filling, because small-sized stones pack closer than large ones, thereby realizing a proportional saving in cement. The tests made to ascertain the comparative transverse strength of different compositions proved that the bond was stronger in béton made with small stone. In breaking test-sections made of béton in the form of bricks, the fracture of those filled with small stone

was almost invariably across the stone lying in the line of fracture, while the fracture of the test bricks made with a filling of stone three or four times larger, showed a frequent tearing away from the bond between the béton and the larger stone filling, the composition of the béton being the same in both cases.

The proportions of cement and coarse beach sand and gravel, used in re-enforcing iron beams for floors and roof supports, were one part of cement to two parts of sand and gravel. The size of the iron beam, selected for an experimental test, was a four-inch I beam of lightest pattern, twelve feet long, weighing thirty pounds to the yard, and its safety load was limited to eleven hundred and fifty pounds. A plank mold was made the length of the iron beam, twelve inches deep by five inches wide, in the bottom of which a layer of béton was first moderately tamped down to an inch in thickness; then the iron beam was laid on the course at equal distances from each side of the mold, and settled down on the surface of the course of béton to a good bearing. This brought the top surface of the beam seven inches below the top of the mold. The work of filling and tamping the courses was then continued until the mold was filled.

The reason for placing the iron beam so near the bottom of the mold was to utilize its tensile quality for resisting the strain below the neutral axis when this composite beam was exposed to heavy loads, while the béton above this line was relied on for resisting compression from load strain. The béton became thoroughly hardened in about thirty days, when the following tests of transverse strength were made. It was placed upon suitable supports, with a bearing of three inches at each end. A lever was adjusted so as to bring the testing load on a knife-edge bearing at the centre of the beam. Weight was then applied to the long end of the lever, until the stress on the centre of the beam reached nine thousand five hundred pounds. Under this load there was a deflection at the centre of the beam of seven-sixteenths of an inch, but not a sign of rupture appeared at any point.

The load was then removed, and the beam returned to the original line it occupied before the test, showing that the combination possesses the essential quality of elasticity in addition to the enormous increase of capacity to resist strain over that which was possible for either material to sustain if used separately and in the same quantity.

It is suggested for future construction that an inverted

beam would furnish a more preferable distribution of iron in the composite beams than the I beams which were used.

The result of this experiment demonstrated the reliability of the composite beam of iron and béton, and showed that the adhesion of the cement to the iron could be relied on under heavy strains; and warranted the adoption of béton re-enforced with small rods for the floors and roofs.

The beams for supporting the floors throughout the house were placed at such convenient distances apart as to insure perfect safety to the floors, and, at the same time, affording ample opportunities for producing the best effects in deep, paneled ceilings.

The beams were all molded in position, where they belonged, both for the floors and roofs, and after the same method that the experimental beam was made. The iron beams varied in width and weight per yard in accordance with their length and the prospective load; the largest being nineteen feet long by seven inches wide. When the combination beams were completed and ready for the floors and roofs, heavy planks were firmly placed in position and securely supported between the beams; the upper surface of these plank foundations being adjusted on a level with the top surface of the molded beams. These planks served as the bottom of the floor molds, and after the béton comprising the floor was hardened they were removed.

Channel ways had been molded in the walls, on a line with the top of the beams, for the purpose of supporting the outer edges of the floors.

Before the floors and roofs were laid, care was taken to cover all the supporting surfaces with paper, to prevent the adhesion of floor and roof sections to their supports. This precaution was necessary, to permit the movement of the floors and roofs that would unavoidably take place under varying temperatures and loads.

A part of the experimental system contemplated an attempt to warm the house by passing currents of heated air between the floors and ceilings, and up through flues made in close proximity to each other for that purpose, in the interior walls of the building, and it was necessary to core out a liberal area of lateral openings through the upper portion of the beams, in order to permit a free circulation of heated air. The ceilings rested upon flanges projecting from the lower portion of the beams, as shown in Figure 1.

Instead of using sand and gravel, or both, in combination with cement, for floor and roof construction, the preliminary experiments that proved the superior value of broken blue stone for massive work, led to the adoption of washed, fine screenings from the same material for the floors and roofs, because its greater angularity than gravel insured a stronger bond in the work than could be realized by using sand and gravel.

The proportions of materials used for this purpose were: one part of Portland cement to two parts of the fine stone screenings. The preparations being completed for laying down the floors, a thin course of the béton was first put on, and evenly tamped down to about an inch in thickness, over the whole space intended to be covered. Then rods of iron, five-sixteenths of an inch in diameter, were placed both longitudinally and laterally, at a uniform distance of eight inches apart, over the whole surface. Then, on this, a final layer of two inches in thickness was carefully tamped down. In about eight hours, the béton was hardened sufficiently to allow the application of the top surface, which was floated down with a half-inch coat of cement and fine beach sand mortar, made of equal parts of each. This completed the final finish, and made the whole thickness of the work three and a half inches. It will be observed that for the same reason as in beam construction, and, as before explained, the iron rods for re-enforcing were placed near the bottom of the work, so as to resist the tensional stresses due to the load, while that due to compression in the upper portion would be sustained by the béton alone. In this manner, and by this process, over thirteen thousand square feet of flooring and roofing were constructed to fill the requirements of the building.

The only test of any consequence upon the combined strength of the floors and beams together was made on a section of the widest floor in the house, where the beams are eighteen feet span and six feet between centres. Casks of plaster were placed upon the floor over the beam, forming a triangular load of thirty tons, which was sustained without any injury to the floor, or measurable permanent deflection. The dimensions of the beam that sustained this load were seven by sixteen inches, and eighteen feet span, re-enforced in its lower portion with a seven-inch I beam, weighing fifty-five pounds to the yard.

This test indicates that in addition to its admitted fire-resisting qualities, the re-enforced system of construction challenges comparison with other methods of building in matters of strength

and of cost, whether for buildings requiring long or short floor spans.

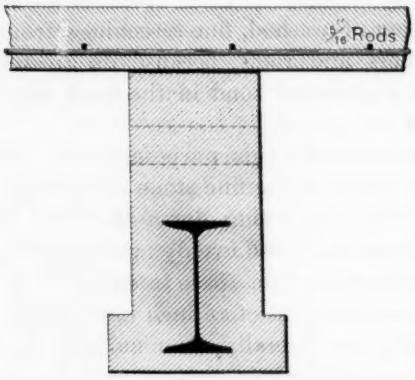


FIG. 1.

Experimental tests were made with several partition walls, to ascertain how thin it would be advisable to construct them for light walls where the load was small. The result of the experiment showed that the resistance of partitions eight feet in height made of béton two and a half inches thick, and re-enforced with one-quarter inch iron rods, was equal to brick walls eight feet high, and eight inches in thickness.

It is the opinion of the writer that for the great majority of houses required for dwelling purposes, a system of thin re-enforced double walls, with a space of from six to ten inches between them and re-enforced cross connections every two or three feet apart, to unite the outer and inner walls firmly together, could be built up to thirty or forty feet in height, at a cost not exceeding that of first-class brick work.

Besides an equal economy in the construction, such double walls would be an incomparably better defense against stormy weather than the best quality of brick work, because the absorptive capacity of béton is so much less than that of brick.

Thus, all things considered, the thin double wall system commends itself as containing the main desirable qualities essential to the outer and inner wall construction of dwelling houses, embracing, as it would, a sure protection against both fire and dampness, and the means for thorough ventilation. Besides the special fitness of the re-enforcing system for floors, roofs, beams and thin walls, it is an interesting question whether the same system may not be also applicable, and advantageously extended to a more general use in many engineering requirements: especially in situations where immense weights must be sustained, and where iron construction alone is difficult of application, notably in such an important work as the Hudson River Tunnel, where its tubular form is constructed with an outer cylindrical shell of flue iron, and

lined inside with heavy brick mason work; much of this tunnel rests upon a treacherous bed of silt, and might be made absolutely safe from a rupture caused by settlement, induced by vibrations resulting from railroad traffic in addition to its own weight, by adding to a thin brick lining a strong béton about sixteen or eighteen inches thick, and working in it three or four courses of iron bars, of suitable size, laid longitudinally and in sufficient quantity to bear any amount of strain that settlement or any other cause might bring upon it. Rings of flat bar iron, interspersed in the béton lining a few feet apart, would further add to its security.

Although the writer has no personal knowledge of the methods which are to be used in filling the interior of the statue of Liberty, to be erected on Bedloe's Island, New York Harbor, he is of the opinion that a filling of béton, re-enforced with iron, furnishes the best method of increasing the stability of that colossal statue.

The re-enforced béton system has also been employed with admirable results in heavy foundations for stationary engines. The writer, three years ago, mounted a two-hundred-and-fifty-horse-power tandem compound engine, of very heavy pattern, on a re-enforced béton bed, twenty-three feet long, five feet wide, and seven feet deep. It is apparently as firm and hard as a single mass of granite of those dimensions. The outboard bearing of the main shaft is also mounted on a single block of the same kind of construction. The cost of these foundations was less than the estimate made for the same in first-class brick or stone mason work.

It has also been used for lining a reservoir of 96,000 gallons capacity, which was blasted into a ledge.

Another great advantage realized in re-enforcing béton with iron, is that the iron overcomes its tendency to check in hardening, however large the surface may be, within useful limits, if the distribution of the iron through the work is made with ordinary good judgment. This is demonstrated in the instance of entire freedom from shrinkage checks in the single section of béton flooring laid in the drawing-room of the house under consideration. Its dimensions are eighteen by thirty-six feet, three and a half inches thick, and there is no trace of a check throughout its whole extent, after a period of eight years since it was laid down; and six years of that time it has been, during winters, more or less subjected to unequal strains from expansion and contraction, caused by its exposure to unequal temperatures, while employed as a trans-

mitting medium of heat for warming the room. The method of heating the house is shown in Figure 2, where the section of a portion of the house exhibits the arrangement of hot room and heating flues in the walls and floors.

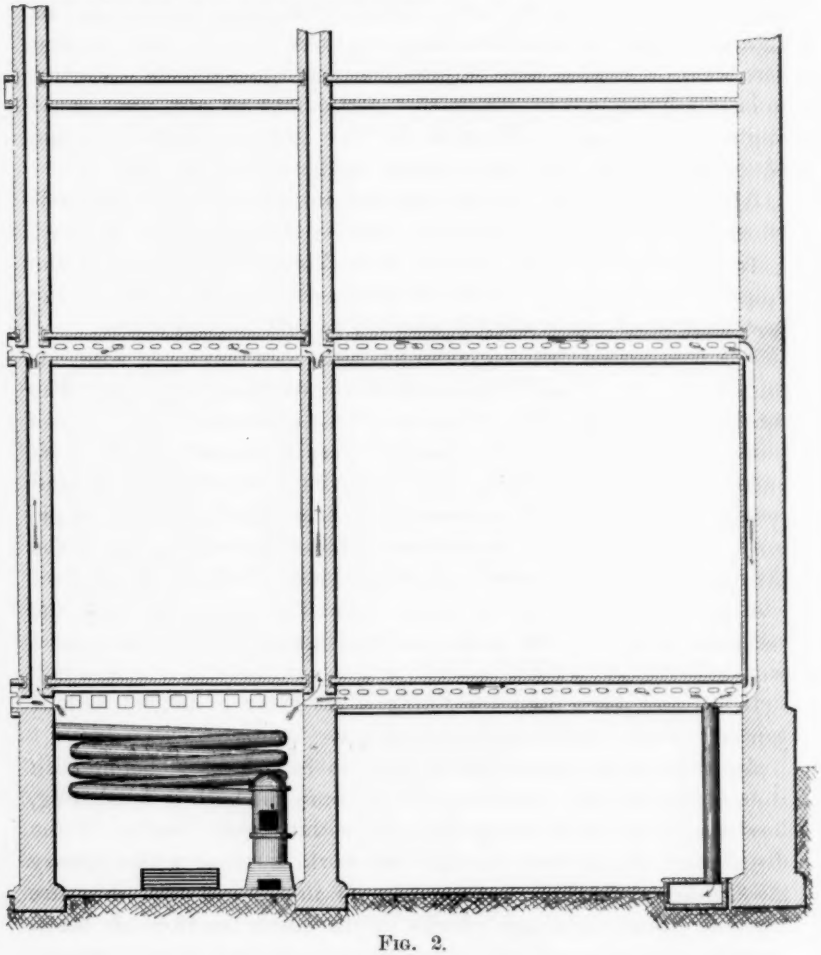


Fig. 2.

In the centre of the cellar is a heating chamber, measuring eleven by sixteen feet, and eight feet in height. Within this chamber is placed an ordinary cast-iron heater, of a capacity for burning about three hundred and fifty pounds of coal per day. Openings were made, about twelve inches apart, all around the top of the surrounding walls of the chamber, leading outwardly to the spaces between

the first floors and the cellar ceilings, and also up through the flues within the interior walls which communicate with the spaces between the second-story floors and ceilings beneath them. Vertical iron pipes, of suitable size, are located so as to connect the open spaces between the cellar ceilings and first floor with a large, closed trunk, or passage-way, which extends nearly all around the inside of the main wall foundation, under the cellar floor, and finally terminates in a large flue, which leads directly under and into the heating chamber.

This comprises about the whole system of arrangements in the construction for warming the house with heat radiated from the floors and interior walls.

Its mode of operation simply consists in the body of warmed air passing from the heating chamber upward, through the walls and under the floors, and in its passage giving up its surplus heat to the surfaces of these flues. As the air becomes reduced in temperature, it naturally descends back through the pipe and trunk passage-ways provided for its return to the heating chamber, where it is again re-charged with heat. It will readily be seen, that, by this method, a continuous circulation will be maintained with the same quantity of air; and, furthermore, that the velocity of the current will vary with the difference of temperature of the air when leaving the heating chamber and re-entering the heating chamber.

By this system there are about fifty-five thousand cubic feet of the interior of the house heated by radiation, through about thirty-five hundred square feet of floor and wall surfaces, and the capacity of the heating chamber is fourteen hundred cubic feet, so there is one cubic foot of heated air to forty cubic feet in the house.

The temperature of the air in the heating chamber averages, in very cold weather, one hundred and seventy degrees, and after delivering its surplus heat to the floors and interior walls, its temperature registers fifty-eight degrees in the flue where it re-enters the heating chamber for re-heating; showing that one hundred and twelve degrees of heat has been given up and utilized for warming purposes. With ordinary care in managing the furnace, a temperature of sixty-eight degrees can be uniformly maintained on the first floor, and from sixty to sixty-two degrees on the second floor, with a consumption of about three hundred and twenty-five pounds of anthracite coal per day in the furnace.

The temperature produced by this system of heating is free from the objectionable extreme variations so common with other modes

of heating. The walls and floor form such large heating surfaces that the temperature is uniform in all portions of the rooms, while the air is not vitiated by escaping gases or heated dust, as is universally the case where furnaces or steam pipes are used for heating.

It is not claimed that its economic result per pound of coal is greater than that which is claimed for the steam or hot-water systems, but if the latter were required to make as liberal a provision for the renewal of fresh air in the interest of an equally good ventilation, the percentage of useful results per pound of coal from steam or hot water would average no higher than the former.

The rain-water falling upon the roof passes through two six-inch iron pipes which are set in the walls, extend across the cellar, and reach into a béton tank in the rear tower, and holding 5,000 gallons, whose water level is thirty inches below the level of the roof. This inverted siphon also forms a distributing system to the various points of consumption in the house, through short branch pipes connected to these mains.

There are also two other tanks made of béton, and holding 3,000 gallons, situated under the main tank. One of these sustains a head of over twenty feet of water, and has never given any indications of leakage.

In regard to the important factor of cost involved in this system of béton construction, its average for beams, floors and roofs, including the supporting platforms for laying them down, was a fraction over sixty cents per square foot. This cost also includes the re-enforcing iron beams and rods. The cost of the heavy wall work, not including cornices, was about twenty-four cents per cubic foot, which includes the cost of plank molds required for building up the walls. The advantages that most favored these economical results were cheap material and cheap labor.

The bulk of the material required for the work abounds in inexhaustible quantities, and is always obtainable at moderate cost. The essential skill required consists in a simple knowledge of the right proportions of material, and of its proper manipulation, both of which can be acquired in a half-day's practice. The most inexperienced laborers can do all the work of the most elaborate béton construction, excepting only the surface finishing, and this, with all the other work, can be superintended by one competent, experienced builder.

Along with the foregoing data, it may be well to include an interesting feature of some experiments that were made to test the heat-enduring qualities of béton. A number of large test bricks were made of the same proportion of materials that was used in the construction of the walls, and in subjecting them to different intensities of heat to see how much they could withstand before breaking up, there was no perceptible difference observed in the tendency to fracture whether the bricks were exposed to a gradual or rapid heating. Not one of them broke when subjected to a white heat. Several were heated to a bright red heat, and then plunged into a bath of cold water. They withstood this test without showing a decidedly damaging fracture, and one of the bricks was exposed to an alternate heating and cooling three times before breaking up.

These results were a surprise, and they suggest the advantage of such a material for the walls of buildings, as a sure defense against uncontrollable conflagrations. The facts that appear to be established by this line of experiments are:

First: That a system of iron beams re-enforced with béton can be made to sustain weights many times greater than the iron beams alone can withstand without re-enforcing.

Second: That floors and roofs can be economically made of béton re-enforced with iron rods, capable of sustaining heavier loads, with a less number of supporting beams, than any other system of flooring and roofing now in use, *at equal cost.*

Third: That the system of re-enforced beams and floors afford advantages for a more perfect system of heating buildings uniformly than by the steam or hot-water systems.

Fourth: That the sanitary requirements of complete ventilation are plainly within the reach of this system of construction.

Fifth, and finally: That it affords a perfect defense against the interior destruction of buildings by fire.

The intrinsic worth of béton construction appears most valuable in furnishing the elements of fire-proof construction; and thus inaugurating a reformation in the prevailing system of building based on the principle that safety from loss by fire can be more economically realized through reformation than by exclusive dependence on insurance to indemnify for losses by fire. The amount of capital destroyed by such losses appears almost fabulous, and has been estimated by insurance authorities to be over one hundred million dollars annually in this country. This enormous amount takes no

cognizance of the losses due to the disturbance of business relations and to labor by such enforced interruptions of industry, but the sum of the losses accounted for seems to be enough to awaken an interest in the discovery of some effective remedy for reducing their magnitude.

Yet, if the remedy is only to be found in building more thoroughly, its adoption may remain doubtful so long as the hazardous way of building and the rates for insuring hazardous property occupy their present relations to each other. Such radical departures from conservative ideas of building, as are herein described, must necessarily find a slow recognition and reach public favor like any other innovation—through small and gradual beginnings—and wait until their merits grow to be regarded as a public necessity.

But, however destructive to the material wealth of the country may be the vast losses of property by fire, they sink completely out of view when compared with the terrible sacrifices of human life that are constantly resulting from unsafe building construction.

Against this fearful consequence of it, humanity can reasonably protest, and claim, for the sake of human welfare, that such structures as hotels, theaters, public schools, and all other places of public resort, shall be made invulnerable to the assaults and the horrors of fire catastrophes.

The writer has heretofore declined to make any public statement concerning the experiments herein described, for the reason that he considered they should undergo thoroughly satisfactory tests of severe weather exposures and varying temperatures through a period of time long enough to determine their true and relative value.

In conclusion, it is to be hoped that these experiments may shed enough additional light on the fire-proof building question to make the way easy for reducing re-enforced béton construction to a system that will deserve public confidence and ultimately lead to its common adoption.

DISCUSSION.

Mr. Grant.—I would like to ask why Mr. Ward did not build his new shop or bolt works on that plan? He has just built a new shop at Port Chester for making bolts. Why didn't he build his shop in that way?

Mr. Woodbury.—The foundation of a straight line engine which runs the screw works is built of béton. (Applause.) The shop in question is his son's—not W. E. Ward's.

Mr. Le Van.—Mr. President, I would like to state, in connection with fire-proof buildings, that the "Brown Building," just finished in Philadelphia from plans furnished by Cabot & Chandler and Amos J. Boyden, is considered fire-proof. All the floors and roofs are of heavy planks on wooden girders, the latter being re-enforced by iron plates or beams *only* where partitions may in future be removed, or where from other causes there may be great weight to support; and in all cases iron so used, has been inclosed in solid wooden beams, and both beams and ceilings thoroughly fire-proofed by heavy mortar coats on strong wire cloth.

All partitions are either brick or tile, and the upper surface of the plank floors is covered with a thick fire-proof mortar coat, over which the finished floor is laid and no *spaces* left for fire or vermin to lurk in.

Where spaces have been unavoidable (as between roof and ceiling in rear part) they have been *filled* with mineral wool.

The stairs are fire-proofed by iron casings, plaster and asbestos paper, and only a light oak finish left exposed.

The insurance companies of Philadelphia considered the risk so small that they have insured this building for five years at the rate of fifty cents on one hundred dollars, or at the rate of one-half per cent, the cheapest rate in the city.

Mr. Woodbury.—That mode of construction is old, and its utility has been tested for many years in New England mills; and this building was planned after a careful study of the principles of slow-burning construction advocated by the Mill Mutual Insurance Companies, and I believe that it is the only commercial building so constructed in this country. I have never known a floor made of plank covered with an inch of mortar to be burned through, although at Allendale, R. I., the whole roof of such a building burned off and endangered the surrounding property without the fire going down through the floor. It is, as far as we have had any experience, a practical impossibility for a fire to burn down through a film of mortar about three-quarters of an inch in the interior of the floor. It would require a great while for such a floor to be destroyed by a fire beneath it, although it would be quite possible. It would undoubtedly not happen until the columns of the beams were destroyed by fire. If the columns were of iron, of course they would yield when subjected to a slight fire; but wood will stand six or eight hours' exposure to intense fire before yielding. If the gentleman will take the trouble to refer to a

paper on mill floors which I read at the meeting in New York a year ago last November, he will see that method of construction described and illustrated by some sketches.

Mr. Le Van.—I did not mean to say it was new. I believe the French do this same thing. I thought from the fact of the rate of insurance being so low that there must be something in this manner of protection that is not generally understood by the community at large.

The President.—The Chair will state that the Zoological Museum at Cambridge is constructed in this way, the beams being covered with a fine covering of mortar attached to wire lathing.

Mr. Root.—Mr. Chairman, Mr. Ward being a neighbor of mine, I have been somewhat familiar with that house during the whole time of its construction. After it was completed he erected a large flagstaff right in the centre of the tower. This staff was supported by iron braces to hold it in place. There came up a very severe thunder storm, and the lightning struck this staff and shivered it into ten thousand pieces. The splinters fell all over the grounds around the house. A short time after that, hearing that the staff had been struck, I went up there, and we went up to the top of the tower to see what damage had been done. We found two or three little splinters of cement. The iron rods in the side walls and floors had served to carry away the electricity to the ground with such ease that no harm was done to the building whatever.

Mr. Weightman.—I would like to ask whether any difficulty has been found from dampness in a house with floors and walls of béton, with flues and ducts in them through which moist air will circulate in a wet season?

Mr. Thompson.—I rise to ask whether it does not take a long time for the béton flues to change their temperature from cool to warm and the reverse? Their necessary thickness and material, it would be thought, would act to make such changes sluggish and lead to trouble.

(*Added since the Meeting.*)

Mr. Ward.—Replying to Mr. Weightman's question, I would say that at no time since the house has been inhabited (which is now about six years) has there been seen the least indication of dampness in any part of it. I attribute its remarkable freedom from this trouble partly to unobstructed circulation of air through all the

walls and the spaces between the floors and ceilings, but mainly to the porous quality of béton, which seems competent to effectually resist any perceptible condensation of moisture. In answer to Mr. Grant's question, I have to say that the Port Chester Bolt Company, like many others entering upon a new enterprise, could not determine how much space they would require for their business short of one or two years' experience, and the building was urgently needed within less time than it would take to construct it of béton. Furthermore, the risk of the building and business from fire is so trifling, in comparison with that of most other manufacturing pursuits, it was not considered necessary to incur the additional cost required to build the factory of béton, although every part of it in the least exposed to dangerous fire risk, as well as the foundation bed of the engine, was constructed of re-enforced béton. To Mr. Thompson's question as to the time required for heating and cooling the house, I would say that a change of temperature in the house is sensibly felt within two hours after fire in the furnace has been started, and it takes altogether about five hours' time to bring the temperature of the space above the first floor up to 68 degrees, when the outside temperature ranges at about 30. To cool off the house rapidly, if necessary, it only requires, after the fire is let down, the closing of the dampers that control the circulation of the heated air and the opening of several windows to admit and discharge a large volume of out-door air. This will in about two hours reduce the temperature of the radiating surfaces from ten to fifteen degrees. Hence there is no serious discomfort experienced from the length of time needed for heating the house nor from reducing the heat when desired.

NOTE RELATING TO "WATER-HAMMER" IN STEAM PIPES.

BY

ROBERT H. THURSTON, HOBOKEN, N. J.

THE action familiarly known as "water-hammer" has been long observed by every engineer who has had much to do with steam power, and its singular effects have been often remarked and commented upon; but these effects have been developed on so large a scale, and have been so serious, oftentimes, in their consequences, as to make it seem desirable to examine into the matter more carefully than has yet been done. The writer has not been able to make a systematic and thorough investigation such as he would have liked to conduct; but some facts have been collected, a few of which will be here presented, that may at least have the effect of calling the attention of engineers more generally to this matter, and may lead to further study of the subject.

When a pipe is filled with steam, and then has introduced into it a quantity of cold water, or when a pipe, itself cold, and containing cold water, even in very small quantity, and without pressure, has steam turned into it, the first contact of the two fluids is accompanied by a sudden condensation which causes a sharp blow to be struck, usually at the point of entrance; and sometimes a succession of such blows occurs, which are the heavier as the pipe is larger, and which may be startling, and even very dangerous.

It is not known, so far as the writer is aware, precisely how this action takes place in all cases, or what conditions are most favorable to the development of the tremendous pressures which are often produced. Perhaps the action is as follows:

The steam, at entrance, passes over, or comes in contact with, the surface of the cold water standing in the pipe. Condensation occurs, at first very slowly, but presently more quickly, and then so rapidly that the surface of contact between the two fluids is broken, and condensation is completed with a suddenness that produces a vacuum. The water surrounding this vacuum is next projected violently from all sides into this vacuous space, and, crossing it, strikes upon the surface surrounding it. As water is nearly incom-

pressible, the blow thus struck is like that of a solid body, and the intensity of the resulting pressure is the greater as the distance through which the portion of surface attacked can yield is less. In this manner enormous pressures are sometimes produced.

In some cases it seems certain that such pressures may be caused at points in the pipe far from either end, and from the point of entrance of the steam. For example, a pipe may lie in a nearly or quite horizontal line, and, if not fully drained, may contain a considerable quantity of water lying in the lower portion, while the steam may flow in above it. The passage of this steam along the surface of the water may cause some disturbance of the surface of the liquid, and this disturbance being gradually increased as the flow of steam becomes more rapid, may finally cause a break in the surface of the water, which disturbance may produce more rapid condensation and still farther agitate the mass, until condensation occurs with such rapidity that a vacuum is formed at the point of greatest action. The next result is the rushing of steam from both directions toward this point, carrying with it, as it goes, masses of water which, coming from opposite directions with enormous velocity, meet at the intermediate spot at which the condensation has been most rapid, and being stopped by instant collision, produce a pressure which may only have as its limit the strength of the pipe.

Where pipes are not burst by this action, it is common to see them sprung and twisted out of line, torn from their connections and, when a succession of shocks occur, as is often the case, the whole line writhes and jumps lengthwise to an extent that is sufficiently serious to cause well-grounded alarm.

The writer had an opportunity to obtain some probably approximate measures of the intensity of this action in long and heavy lines of pipe. Four lengths of 8-inch pipe had been split in this way and it was desired to ascertain whether they remained, in their injured condition, strong enough to bear the ordinary steam pressure of the line from which they were taken. This never rose above fifty or sixty pounds per square inch. They were therefore subjected, in a proving-machine, to gradually increased pressures until the already fractured parts were still farther injured, the repairs, or rather the patching having been carefully done in such a way that they were not strengthened by it. This was done by putting on soft patches along the line of the pipe and securing them by bolts which were set in the line of the split. The patches

thus served as simple stop-valves, preventing the exit of the water through the break.

The following are the results of the tests:

Pipe No. 1.—This pipe was split near one end, for a distance of 15 inches, along the line of the weld. When placed in the proving-machine, it bore the applied pressure until it attained an intensity of 400 pounds per square inch, when the split suddenly extended about ten inches; the pressure could no longer be kept up, and the test terminated.

The pipe was then taken to a pipe-cutting machine and the injured part cut off. It was then again subjected to pressure. It bore a pressure of 1,100 pounds per square inch—the highest that it was convenient or customary to apply to that size—and was taken out sound.

Pipe No. 2.—This length was cracked for a distance of 15 inches along the line of weld, not far from the middle of its length. The crack had opened a little and the pipe was slightly bulged. This piece bore 300 pounds and then gave way, the fracture extending just enough to let off the pressure.

At the opposite end of the pipe was another split, 8 inches in length. The part just fractured was cut off, and the remaining portion was again subjected to the water-pressure. This time it bore 1,050 pounds per square inch when the crack was started and ran about 15 inches. It began leaking, and showed plainly the effect of the pressure at about 800 pounds.

This was an unusually interesting specimen, as the pipe had been bulged considerably by the water-hammer along the line of the 8-inch crack. The pressure afterward borne, therefore, seemed to the writer to be likely to be a fair measure of that produced originally by the water-hammer. Such bulging as was here seen never occurs at usual pressures. The new break did not follow the weld, but ran irregularly, and apparently indifferently, through weld or solid iron.

Pipe No. 3.—This length was split for a distance of 22 inches, the end of the break being about 3 feet from the end of the pipe. It sustained a pressure of 250 pounds. The sound part of the pipe was then tested up to 1,050 pounds without injury.

Pipe No. 4.—This piece was split, like the last, and to just about the same extent, was tested similarly, and gave way at 300 pounds per square inch.

All of this pipe was 8-inch pipe, $\frac{3}{8}$ inch thick, and made with the

usual form of lap-welded joint. The welds were not always perfect, as is probably the fact with all such pipe; but this pipe, butt-welded, would have borne very much higher pressures than those to which it was subjected in ordinary work, by the steam carried on the line. It cannot be asserted that these lengths of pipe did not split under pressures less than those to which they were afterward subjected in the tests, as it is very possible that the first blow may have found a weak part of the pipe, and the split may, in some cases, have extended to a stronger portions. Nevertheless, the writer is inclined to believe that this was not the case in all instances, and is convinced that, in one case at least—that of the 8-inch crack, which was accompanied by a decided bulge in the pipe—the water pressures, at the test, were, at least approximately, equal to, and are very likely to have exceeded, those obtained at the later test. It seems very certain that we may consider it as proven that the pressures produced by "water-hammer" are often enormously in excess of those familiar to us in the use of steam, and that they have, in many cases, exceeded 1,000 pounds per square inch. It is, then, evident that it is not often safe to calculate upon meeting these tremendous stresses by weight and thickness of metal, but that the engineer must rely principally, if not solely, upon complete and certain drainage of the pipe at all times as the only means of safely handling steam in long pipes, such, especially, as are now coming into use in the heating of cities by steam led through the streets in underground mains.

The facts here presented have been, to the writer, something of a revelation, and have seemed to possess unusual interest and importance to the engineer using steam under such conditions as are here referred to. It is a fact which has long been well known, that these suddenly produced pressures are often very great. The writer has occasionally, for many years, known of serious and sometimes fatal, accidents due to this cause; but that these stresses are often as great as is here indicated has probably been little realized by engineers generally.

DISCUSSION.

Mr. Chas. E. Emery.—Last fall the New York papers were filled with accounts of explosions of steam pipes, and in spite of all protests they refused, except in their advertising columns, to call attention to the fact that there were two steam companies in that city, and that the difficulties complained of were on the lines of but one of them.

Few read the advertisements, and the press outside of New York copied only the news items; so to this day there is a general impression all over the country that steam enterprise in New York has been a failure. While, ordinarily, engineering facts are valuable, without reference to time, place or persons, the above statement, with some explanations farther on, show the necessity in this case of stating at the outset that the New York Steam Company has been supplying steam continuously since April of the year 1882, while another company, viz., the American Heating and Power Company, upon whose plant, as is well known, Professor Thurston reported, actually ceased operations early in the winter of 1882–83, after a few months' abortive trial, and is now in the hands of a receiver, who is endeavoring to sell the property in the interest of the bondholders.

The phenomena of the water-hammer is familiar to most steam engineers, particularly those who have had to do with the large pipes used on ocean steamers. The writer, from his connection with the New York Steam Company, had full opportunity to observe the operations of the American Company, and is surprised to find in the paper under discussion no reference to what he considers one of the chief causes of the difficulty experienced in operating the pipes of that company.

It was actually and persistently attempted to carry superheated steam in their underground pipes. The regular superheaters provided were never used, but a series of pipes in the boiler settings answered the purpose to a certain degree, superheating the steam, it was said, some 60° or 70°—probably more at times, as the demand for steam varied; for who could regulate such an apparatus, or, in fact, in regular practice, any apparatus for such a purpose? The results are evident on consideration. The branches of the line where little or no steam was used soon cooled down, so as to contain only saturated steam, and at times all the branches were in this condition. Upon opening a valve anywhere, however, a circulation would be established, which slowly but surely would bring the superheated steam into that line, and all the conditions to produce unusual strains or cause even an explosion, would be present as soon as the steam reached any collection of water; for the reason that water, which is harmless in the presence of saturated steam of the same temperature, would act as an efficient refrigerator of steam at a higher temperature, though of the same pressure as that due to the temperature of the water.

The reduction of volume thus caused would not be as great as if steam were brought in contact with cold water, but entirely sufficient to cause a flow of steam from both—and at junctions from several—directions, some of the currents perhaps bringing more water to reduce the volume of more steam, thereby causing collision with a necessary great increase of local pressure, straining the pipes, causing the joints to leak at all sorts of odd places where there were apparently no reasons for the difficulties. The more violent explosions were undoubtedly due to a combination of the straining effects due to the reduction of volume of superheated steam, with the more potent one of direct contact of steam with water cooled during times of inaction; below the temperature due to the pressure, the forces being brought in action more strongly when the steam was conducted through one pipe to heat an adjoining one.

The conditions which brought about the bursting of the pipes undoubtedly varied with the circumstances of each particular case, and with the peculiarities of each location. Extreme business pressure prevents the writer from fully discussing the subject at this time, and its farther consideration must be left for a proposed paper on the general subject of "District Steam Systems," which it is expected will be prepared when all the problems necessary to a complete mechanical and financial success shall have been analyzed and the necessary apparatus put in practical operation.

NOTES ON STEEL.

BY

GUS. C. HENNING, M.E., PITTSBURGH, PA.

THE use of steel as a material of construction is becoming so general, that it is no longer a question whether we can obtain a material which can be relied upon, but merely when steel is used whether the sections of individual members will not become too light, when of the same strength as designs in iron, so that the structure will be destroyed by corrosion or minor accidents, rather than by use, unless unnecessary weight is added.

It is a well known fact that the sole reason why perfectly homogeneous Bessemer steel is not made in this country, is this: that there is a greater profit in steel for rails, with less work, than there is in steel for structural purposes, in addition to the fact that rails can be made in stock, but shapes cannot very profitably.

It is but quite recently that any attempt has been made to obtain a perfectly reliable and uniform material on a large scale, and then generally by using Siemens or Pernot furnaces.

In England, France, Belgium and Germany, the state of structural steel manufacture is far advanced, and for the simple reason that engineers in those countries insist upon a uniform material, and the quality of the output of any works determines its commercial success and progress, rather than location or political or personal influence. In this country the larger structures designed of steel are few in number, and the following table is a complete list to date.

DATE.	NAME.	ENGINEER.	SHOPS.	STEEL WKS.	WEIGHT OF STEEL. Tons.	CLASS OF STEEL.
	St. Louis Bridge.	J. B. Eads.	Keystone.	Butcher.	2,900	Carbon & Chrome.
1879–83	East River Bridge.	W. A. Roebling. Wm. Hildenbrand.	Edgemoor.	Cambria.	6,300	Bessemer.
1880	Plattsmouth Bdg.	Geo. S. Morison.	Keystone.	.....	497	Siemens-Martin.
1881–82	Bismarck Bridge.	"	Detroit.	Spang Steel & Iron Co.	....	.....
1883	Blair Bridge.	"	Keystone.	Cambria.	422	Open Hearth.
1883	Willamette Bdg.	"	Edgemoor. Passaic R.M.Co.	Spang Steel & Iron Co.	(?)600	"
1883	Niagara (New R.R.)	C. C. Schneider.	Cent. Bdg. Wks.	"		"
1883	Point Pleasant.	Col. Seymour.	Keystone.	"	(?)	"

The steel for these structures, as far as completed, was quite uniform in chemical analysis, as well as in mechanical properties, and

in every way superior to and more satisfactory than any grade of bridge iron from any mill.

Imperfect welds are not to be feared, as welding was in no case permitted; any hard spots could be easily removed by careful and thorough annealing.

It is true that some of this material was abused during fabrication, from want of knowledge of and experience in the use of steel, but this could have been prevented by proper procedure; where proper care was bestowed upon the work there remains no doubt about the superiority of the structure.

The quality or uniformity of the material used in any structure depends mainly upon the kind of inspection it receives at the steel works, while the quality of the structure depends upon the experience and care of the inspecting engineer at the bridge shops; if the former performs his duty faithfully and accepts only such material as is fully up to the specification requirements, and the latter watches closely every process during fabrication and prevents all abuse, there is but little doubt that a superior structure will be obtained. This, of course, requires experienced inspectors, whose judgment must be correct and based upon fact, and who, at the same time must be on duty at the bridge shops at all hours with the men.

Below is given a table, containing a number of tests of eye-bars which were recently made at the Keystone Bridge Works, and the results of which are equal, if not superior, to anything that has been done heretofore.

The tests as given in Table No. 1 were made upon bars fabricated by the following method:

The bars were at first heated in the neck, while the end was protected from the heat by a covering of refractory material; upon reaching a bright red heat, the bar was placed in the hydraulic upsetting machine and partly upset. Whenever this upset showed any wrinkles or uneven edges, these were drawn down under a helve hammer and fullered out. Then the bar was returned to the furnace and heated nearer the end, and again upset and worked under the helve hammer. Three heats complete such an upset, when the bar is again heated to a bright red and the eye is shaped in the hammer die, from which the bar is taken to another helve hammer, under which it is drawn down to the required thickness and given the correct set. This sometimes requires another heat before the end is finished, when the eye at the other end of the bar is made in the same manner.

TABLE No. 1.

Material.		Specimen.		Fractured Section.			Elast. Limit. lbs. per sq. inch.	Ultimate Strength. lbs. per sq. inch.	Elongation.		Broke from Pin Hole.		Excess.
		Size.	Area.	Size.	Area.	% Red.			In 13 ft.	%			
	14 ft. 4 in. c. to c.	5 × 1	4.80	.....	.....	44.1	41,800	72,700	.....	11.8	3 ft. $8\frac{5}{8}$ in.	$4\frac{1}{8}$" pins.	52.5%
		5 × 1	4.80	.....	.....	38.0	41,632	73,000	....	12.2	3 ft. $6\frac{1}{4}$ in.		"
		5 × 1	4.80	.....	.....	35.5	43,700	74,590	.....	13.0	8 ft. $2\frac{3}{8}$ in.		"
		5 × 1	4.80	.....	.....	35.2	44,272	75,130	.....	13.0	1 ft. 10 in.		"
		5 × 1	4.80	.. ...	.....	44.1	44,000	74,050	... .	13.5	8 ft. $3\frac{1}{4}$ in.		"
		5 × 1	4.80	.....	.....	43.7	44,000	73,330	.....	13.8	3 ft. $3\frac{1}{8}$ in.		"
	$22\frac{3}{4}$ ft. c. to c.	$6\frac{1}{2}$ × 1	6.50	.....	.....	43.8	40,026	68,380	in 20 ft.	13.5	4 ft. $0\frac{3}{4}$ in.	5" pins.	38.5%
		$6\frac{1}{2}$ × 1	6.50	.....	.....	43.0	40,766	69,222	....	13.5	3 ft. 8 in.		"

Note.—Fractures were all perfectly uniform, showing a very fine crystalline structure perfectly homogeneous, and the broken surfaces showed perfectly symmetrical arrangement of material about the two axes; this latter is also a criterion that the strain was applied properly without disturbing influences.

Both eyes having been thus forged, the bar is taken to the annealing furnace, where it is subjected to a gas flame until attaining a bright red heat, when it is allowed to cool down very slowly until sufficiently cool to be handled. Then the bar is straightened in a bending machine, after which the pin-holes are bored in the head.

Thus it will be seen that these steel bars are subjected to four bright red heats and one annealing heat.

The bar is at no time allowed to reach a white or melting heat, and consequently the steel is not deteriorated, and but slightly altered in chemical composition, as has been shown by the series of tests made by Mr. J. F. Barnaby (see London *Engineering*, April 20th, 1883).

Table II. gives results of tests of three steel eye-bars—welded, not upset—made by the Springer patent process, from open-hearth steel made by the Spang Steel and Iron Co.; they were exhibited at the Railroad Exposition at Chicago, and the results were there given in a pamphlet from which this is taken.

The accompanying figure shows the method of manufacture:

The bar is first trimmed off at the ends to be round, and a bent bar of U shape is then placed around it to fit the bar closely; cover plates are then placed above and below, and the whole heated to a good welding heat, upon which the exact shape of head is formed under the steam hammer.

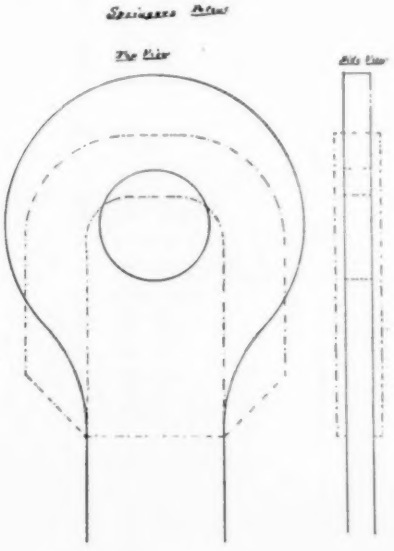


TABLE II.

Tests of Welded Steel Eye-Bars.

(Made According to J. H. SPRINGER's Patent.)

SPECIMEN.		FRACTURED SECTION.			ELASTIC LIMIT.		ULTIMATE STRENGTH.		ELONGATION.		DISTANCE OF POINT OF FRACTURE FROM BACK OF NEAREST PIN HOLE.
Size.	Area in □ in.	Size.	Area in □ in.	% Reduct.	On specimen.	Lbs. per □ in.	On specimen.	Lbs. per □ in.	In 8 ft.	%	
5″ × 1″ × 10 ft. 10 in.	5	$4\frac{1}{8}$″ × $\frac{5}{8}$″	2.578	48.4	179,400	35,880	286,000	57,200	1.333 ft.	16.7	1 ft. $3\frac{1}{2}$ in.
5″ × 1″ × 10 ft. $9\frac{1}{2}$ in.	5	$3\frac{3}{16}$″ × $1\frac{1}{16}$″	2.621	47.6	178,100	35,620	289,900	57,980	1.542 ft.	19.3	2 ft. $7\frac{3}{4}$ in.
5″ × 1″ × 10 ft. $9\frac{1}{8}$ in.	5	$3\frac{5}{16}$″ × $\frac{3}{4}$″	2.953	40.9	175,500	35,100	291,200	58,240	1.738 ft.	21.7	2 ft. $4\frac{3}{4}$ in.

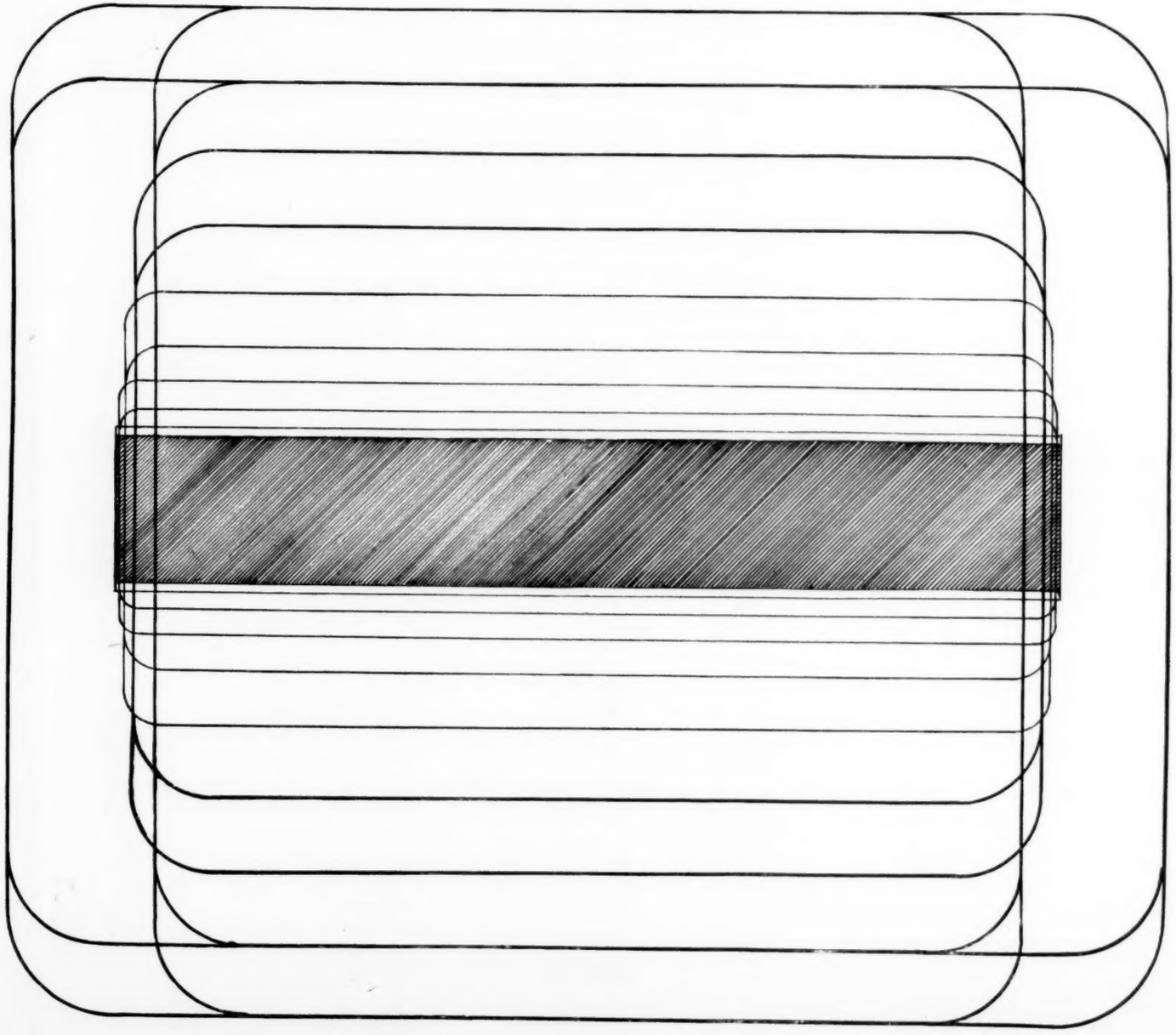
Heads $11\frac{3}{4}$″ diameter by 1 inch thick. Pin holes $4\frac{1}{8}$ in. diam. Bars were not annealed. Low Bessemer steel .10% of carbon.

Made by and tested at Keystone Bridge Works.

Fig 2

SUCCESSIVE SECTIONS OF BILLET.

Roughing Passes
Area
55.68 sq.in.
47.62 " "
41.62 " "
35.62 " "
30.97 " "
24.72 " "
Time 5 min.



Finishing Passes.
Area.
19.07 sq.in.
14.29 " "
11.40 " "
8.48 " "
7.31 " "
6.50 " "
Time 8 min.

The appended report at the end of this paper contains the results of tests of six steel bars all $6\frac{1}{2} \times 1$ in., 22 ft. c. to c. of eyes, kindly presented to me by Mr. A. Gottlieb, President Keystone Bridge Co., which were tested at Watertown Arsenal, and were made by above process, of open-hearth steel made at Cambria Iron Works.

An inspection of this report will show that these bars are very uniform in most qualities, especially so in the elastic limit and the modulus of elasticity.

The entire method of manufacture of the steel is also given, as well as the chemical analysis of each head and bar, all bars having been rolled from the same blow of steel, and by the same method in a bar mill by the successive reductions as shown by Fig. 2, on which the sectional area of bar in each pass is given.

In the report of analyses supplied to me by Mr. George S. Morison, C. E., it will be noticed that in P_1 4585 and L_1 4587, the quantity of silicon is quite abnormal; this cannot be ascribed to the chemists, Messrs. Hunt & Clapp, of Pittsburgh, as independent analyses were repeated with the same results. As all the surface metal, about $\frac{1}{16}$ inch deep, was removed before collecting drill chips for analyses, the result must be ascribed to a peculiar composition of the heads.

TABLE OF CHEMICAL ANALYSES.

Chemical Analyses of $6\frac{1}{2} \times 1$ in. steel bars. Borings taken from each head after removing surface scale. Pernot open-hearth steel from Cambria Iron Co., of Johnstown, Pa.

Analysis of bars *before annealing.*

	CARBON BY COLOR.	MANGANESE.	SILICON.	SULPHUR.	PHOSPHORUS.	COPPER.
	0.270	0.380	0.036	0.075	0 090	Trace
After annealing...	0.270	0.387	0.031	0.074	0.090	Trace
	ANALYSIS OF EACH HEAD OF SIX EYE-BARS TESTED AT WATERTOWN ARSENAL, MADE FROM ABOVE STEEL.					
M_1 4,582.....	0.300	0.710	0.028	0.092	0.098	0 032
M_2 4,582.....	0.300	0.620	0.023	0.087	0.089	0.030
D_1 4,583.....	0.280	0.730	0.016	0.090	0.097	0.030
D_2 4,583.....	0.280	0.580	0.019	0.085	0.084	0.030
Z_1 4,584.....	0.280	0.650	0.023	0.081	0.092	0.035
Z_2 4,584.....	0.280	0.670	0.014	0.072	0.085	0.030
P_1 4,585.....	0.300	0.640	0.070	0.095	0.093	0.035
P_2 4,585.....	0.300	0.670	0.011	0.072	0.086	0.035
U_1 4,586.....	0.300	0.640	0.011	0.067	0.087	0.040
U_2 4,586.....	0.280	0.650	0.018	0.060	0.081	0.040
L_1 4,587.....	0.280	0.690	0.046	0.074	0.074	0.035
L_2 4,587..... ...	0.280	0.670	0.011	0.069	0.083	0.030

It is a well-known fact that punching or shearing steel will injure any bar very materially, and the only method of restoring such material to its original condition is to ream out all holes or to plane off sheared edges unless there is an excess of metal at such edge.

To avoid these injurious effects, small holes are punched in steel which are afterward reamed or drilled out to their full size, and the necessity of such a course is represented by the figures subjoined, which give results of tests made on steel bars for the East River Bridge, at Edge Moor Iron Works, by the writer in 1880. These figures also show to what distance from the edge of a hole the

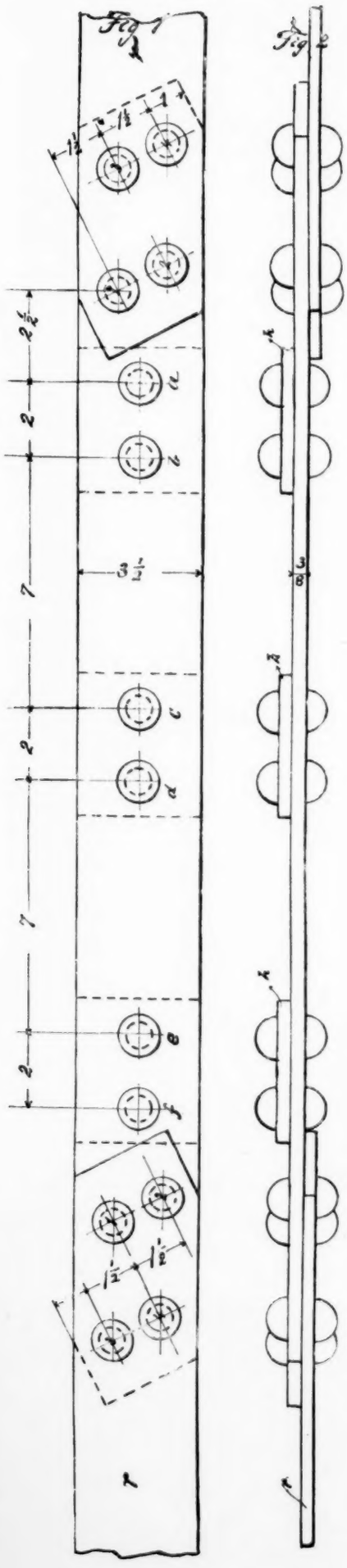


Fig. 3

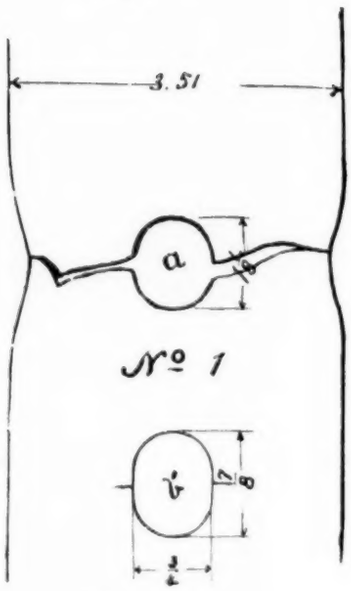
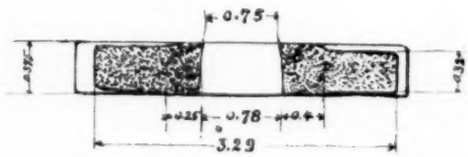


Fig. 4



Holes 1, 2, 3 & 4 were punched $\frac{7}{8}$ in. diam. & then reamed out to $\frac{3}{4}$ in. diam.; holes a, b, c, d, e & f, were punched $\frac{3}{4}$ in. & not reamed. In this bar no plates "h" were rivetd on, and the holes a, b, c. etc. were left open

Elastic limit was reached at 45,655 lbs. pr. sq. in.

At 59,266 lbs. all rivet holes (punched) showed cracks as indicated at "b" in Fig. 3.

Bar broke at 58,770 lbs pr. sq. in., with fracture, represented in Fig. 4

Rivet holes a-f, elongated as at "b", Fig. 3.

Stretch 0.8 in. in 25 in. = 3.2 %

Holes
all other
Elastic
broke
This ba
crysta
section
off
of over

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Fig. 5

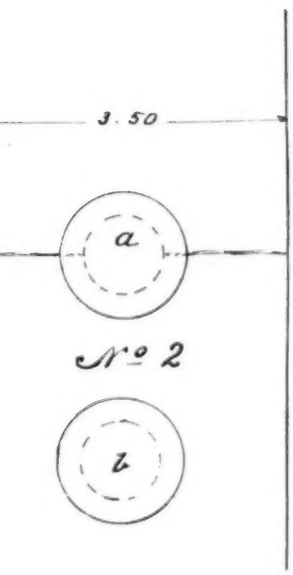

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Fig. 6

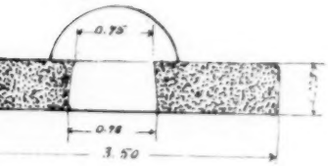

Fig. 7

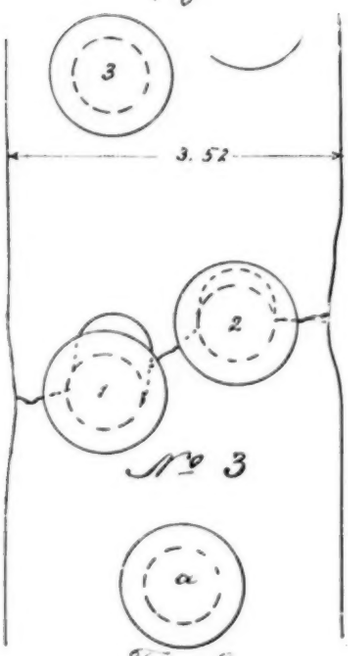

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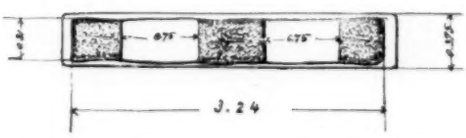
Fig. 8



Fi

...es a-f, punched by "Spiral Punch."
...thers reamed.
...stic limit 56,921 lbs pr. sq. in.;
...ke at 60,641 lbs pr. sq. in.
...c bar showed uniformly large
...rystals, and did not reduce in
...ction, nor elongate, but broke
...f suddenly, without giving signs
...weakening.

All holes "reamed" after punching holes with $\frac{5}{8}$ in. punch, so as to make $\frac{3}{4}$ in. reamed holes.
Elastic limit 55,487 lbs pr. sq. in.;
broke at 80,830 lbs pr. sq. in.
Stretch was 0.35 in. in $22\frac{1}{2}$ in. = 1.55%
Fracture showed slight crystallization at edges of bar, and some lamination at centre, as shown by Fig. 8

Holes "a-f
all others punc
to $\frac{3}{4}$ in. diam
Elastic limit
broke at
Stretch was
Fracture show
brilliant at the
crystallization
by Fig. 10.
coarse crystals,
had taken pla

Tests of Steel Floor-beam-lattice-bars
for East River Bridge,
made by
G. C. Henning. Aug. 19 & 20th 1880

Fig. 9

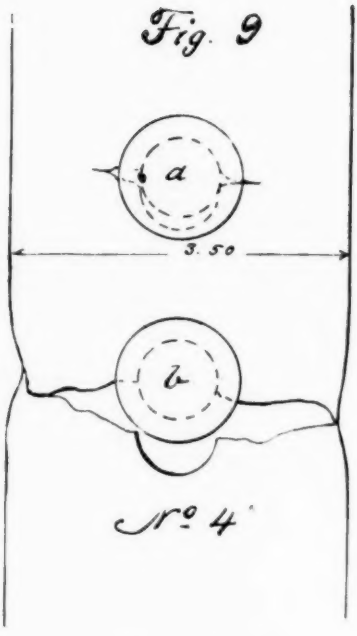


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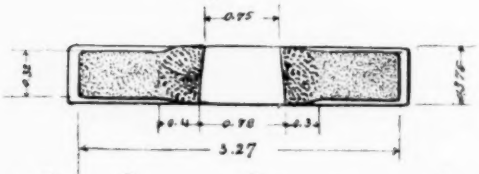
Fig. 10



nuching
e make

. in.;
g. in.

in. = 1.55%
tallization
lumination
g. 8

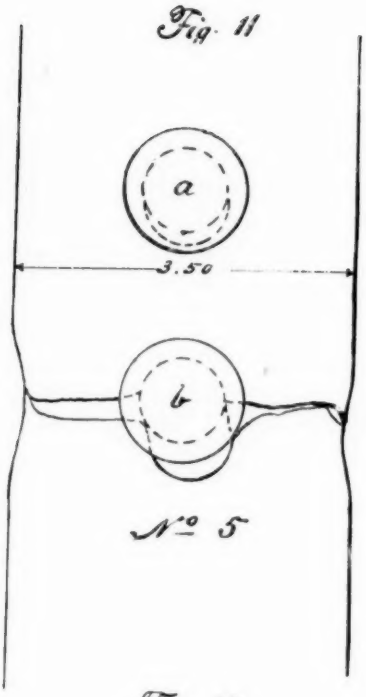
Holes "a-f," punched by $\frac{3}{4}$ in. punch, all others punched by $\frac{5}{8}$ in. punch & reamed to $\frac{3}{4}$ in. diam.

Elastic limit 55,809 lbs. per sq. in.; broke at 52,604 lbs. per sq. in.

Stretch was 0.6 in. in 24 in. = 2.5%

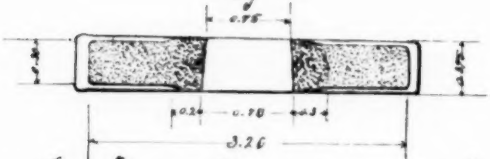
Fracture showed extremely fine grain, brilliant at the edges, and very coarse crystallization around hole; as shown by Fig. 10. Where ber showed such coarse crystals, no reduction of thickness had taken place.

Fig. 11



№ 5

Fig. 12



Holes "a-f," punched by $\frac{3}{4}$ in. punch, all others punched by $\frac{5}{8}$ in. punch & reamed to $\frac{3}{4}$ in. diam.

Elastic limit 53,214 lb. pr. sq. in.

broke at 55,687 lb. pr. sq. in.

Stretch was 0.5 in. in 24 in. = 2.08%

Fracture was same as in №. 4, except there was no brilliancy at edges.

See Fig 12.

steel is affected by punching, and how much ought to be reamed out to restore the material to its original condition.

TABLE OF PHYSICAL TESTS.

Steel for East River Bridge.

Physical tests of the same steel made on $\frac{3}{4}$ in. round rolled bars made from test ingots.

No. of heat.	Diameters.		Area.			Elastic Limit.	
	Original.	Fract'ed.	Original.	Fract'ed.	% Reduction.	Load applied.	Lbs. per □ in.
a 3,424	.746	.550	.4371	.2376	45.66	21,000	48,040
b 3,424	.747	.505	.4383	.2003	54.20	18,500	42,210

Ultimate Strength.		Elongation.		Modulus of Elasticity.
Lbs. applied.	Lbs. per □ in.	Actual in 8 in.	% of 8 in.	
a 31,975	73,150	1.79	22.37	28,210,000
b 30,450	69,470	2.05	25.62	29,210,000

a was not annealed; *b* was annealed.

These experiments also tend to show that in most cases the punches used have been too large in relation to the size of finished holes; when it is remembered how poorly holes punched in pieces longer than twenty feet match when superposed, it will be readily seen how imperfectly holes will be reamed when but such a small amount is taken off the edges, as was the case in all of the East River Bridge work, in which many of the most important members were nearly or quite 40 feet long. The inference drawn from these tests must be that it cannot but be very defective work in which all holes were reamed so little.

In better work, holes are reamed out $\frac{1}{4}$ inch measured on the die-side of the material punched, and if in this case the holes are not truly matched they will still be reamed out on their entire circumference. The former method was adopted on all of the work for the superstructure of the East River Bridge, holes reamed $\frac{1}{8}$ inch

on punch side of material, while the second method, holes reamed $\frac{1}{4}$ inch on die side was adopted on all steel bridges designed by Mr. George S. Morison, C. E.

In the first case, a large percentage of the holes were reamed out on one side only and left rough on the other; in the second case, there are but very few holes indeed which have not been reamed at every point: in fact, a careful count showed less than one per cent. of holes not entirely clean.

It has often been remarked that drifting or cold straightening ought not to be tolerated in steel work under any condition or circumstances, and as an example of the extremely injurious effect of such treatment, I will mention the case of the boilers of the Russian imperial yacht "Livadia," which were all condemned, being absolutely worthless and broken by the carelessness or ignorance of the mechanics. These boilers were constructed of low carbon steel, but drifting the holes and setting the edges of the plates at the joints, when cold, actually ruptured the plates so that the hydraulic test could not be applied on account of leakage.

The effect of drifting is shown more plainly in the accompanying illustration, which is taken from an actual case. A few weeks ago a steel plate 26 inches by $\frac{1}{2}$ inch thick, and about 26 feet long, was dropped and badly kinked at one edge near the centre; this kink, produced by careless handling, extended about $5\frac{1}{2}$ inches along the edge, and one inch back from it. At the point of greatest depression, the edge dropped below the general surface of the plate about $\frac{1}{2}$ inch, or about the thickness of the plate. At one end of the distortion, the edge was raised about one-quarter inch above the general surface of plate as shown at right hand end of distortion.

Upon seeing this, the question was asked whether and how this defect could be straightened out without destroying the plate. It is a very easy matter to injure a plate in such a manner, but extremely difficult to restore the plate to its former condition.

As it would be a great waste to condemn such a plate which was otherwise perfect, and it would cause considerable delay to replace it, it was suggested to heat the plate to a dull red and hammer the plate on a flat anvil block with heavy sledges, hoping thus to avoid the deteriorating effect of cold straightening.

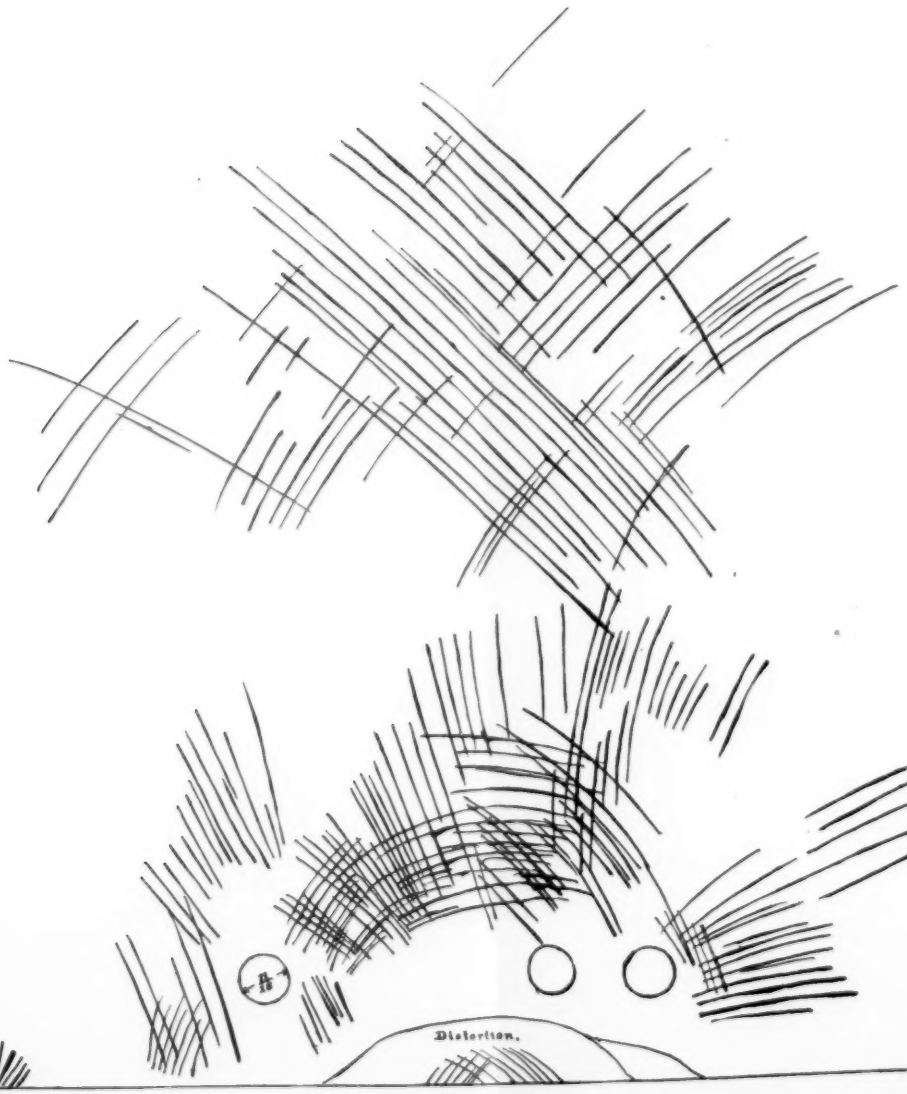
After the job was finished the plate showed marks which the figure represents, also, showing the full width of plate, location of rivet-holes (on die side) and the peculiar lines which can always be traced

26"x1" Plate.

Lines of Stress

G.C.Henning M.E.

June 1883.



Distortion.

on steel around a spot which has been overstrained. These lines show where the excessive stress produced by hammering broke off the scale, forming bright lines here indicated in black, and which are of perfectly regular spiral form which it is not difficult to follow.

This straightening was done with the greatest care and precaution, and no trouble spared to do a good job, and still—see the result! Is it to be wondered at that incompetent men will ruin a steel fabrication, or that some "engineers" say that steel is unfit as a material of construction.

But there is a remedy for all this, which must be plain to all, and can be best expressed by the old proverb, "Prevention is better than cure." Start the work correctly in the first place, use nothing but straight shapes, and condemn all abuse and carelessness, however slight, and half the battle is won; but let the bad practices once obtain for ever so short a time and it will be impossible to break them.

These remarks and tests tend to show several things in regard to fabrication of steel work, namely: "Steel eye-bars can be made perfect in every respect, much superior to those of iron; and methods used in shops at the present time must at an early day be superseded by such as will insure better work." An additional point of the greatest importance is this; with current prices of labor and material, not only in Pittsburgh, but in Eastern shops as well, steel work is a little cheaper than iron for all large structures. The ultimate strength of steel, such as is commonly used for structural purposes, is to that of iron as 100 : 71, or as 100 : 65 when comparing the elastic limits, while the relative cost of steel to iron, as taken from contract prices obtaining at present is as 100 : 74. Thus basing all calculations of parts on the elastic limit of the material and the cost on current prices, the relative cost of an iron and steel structure for the same work, will be as $\frac{65}{100} : \frac{100}{74} = 85.8 : 100$, not considering a smaller freight account, there being less material in the work; nor cheaper erection, work being less cumbersome.

TENSILE TESTS OF STEEL EYE-BARS.

BY

GUS. C. HENNING, M.E.

WATERTOWN ARSENAL, MASS.,
June 12, 1883.

Report of Mechanical Tests made with the 400 *ton U. S. Testing Machine.*

Tests made by James E. Howard. No. 4582.

Sectional area, 6.35 □″; *gauged length*, 160 *in.*

Loads Applied.		In Gauged Length.		Elongation.	Remarks.
Lbs. Total.	Lbs. per □ in.	Elongation.	Set.	Centre to Centre of Pins.	
6,350	1,000	0	.....	0	Bar 6.48″ × 0.98″.
31,750	5 000	0.0265	.....	0.06	
63,500	10,000	0.0551	.....	0.12	
.....	1,000	.....	0.0015	0.015	
95,250	15,000	0.0825	.....	0.17	
127,000	20,000	0.1094	.....	0.23	
.....	1,000	.....	0.0016	0.02	
158,750	25,000	0.1363	.....	0.28	
.....	1,000	.....	0.0018	0.035	
160,000	.....	0.1373	.....	.....	
165,000	.....	0.1420	.....	.....	
170,000	.....	0.1464	.....	.....	
175,000	.....	0.1504	.....	.....	
180,000	.....	0.1548	.....	.....	
185,000	.....	0.1590	.....	.....	
190,000	.....	0.1632	.....	0.34	E = 29,880,000.
.....	1,000	0.0025	.....	0.05	
192,000	.....	0.1648	.....	.....	
194,000	.....	0.1664	.....	.....	
196,000	.....	0.1680	.....	.....	
198,000	.....	0.1700	.....	.....	
200,000	.....	0.1715	.....	0.36	
202,000	.....	0.1730	.....	.....	
204,000	.....	0.1750	.....	.....	
206,000	.....	0.1764	.....	.....	
208,000	.....	0.1782	.....	.....	
210,000	.....	0.1800	.....	0.39	
212,000	.....	0.1818	.....	.....	
214,000	.....	0.1832	.....	.....	
216,000	.....	0.1850	.....	.....	
218,000	.....	0.1865	.....	.....	
220,000	.....	0.1882	.....	.....	
222,000	35,000	0.1900	.....	0.43	
.....	1,000	.....	0.0020	0.09	
224,000	.....	0.1920	.....	.....	

Head.	Diam.	Thickness.	Pin diam.	Width back of pin.
M_1	14″.00	1″.07	5″.02	5″.55
M_2	13″.98	1.00	5.02	5.64

Bar 221.88 in. c. to c. of pin holes.

Loads Applied.		In Gauged Length.		Elongation.	Remarks.
Lbs. Total.	Lbs. per □ in.	Elonga. tion.	Set.	Centre to Centre of Pins.	
226,000	.....	0.1934	.....	.....	
228,000	.....	0.1955	.....	.....	
230,000	.....	0.1975	.....	.49	
232,000	.....	0.1994	.....	.....	
234,000	.....	0.2012	.....	.....	
236,000	.....	0.2033	.....	.....	Elastic limit.
238,000	37,480	0.2055	.....	.....	
240,000	.....	0.2100	.....	0.56	
242,000	.....	0.2160	.....	.....	
244,000	.....	0.2233	.....	.....	
246,000	.....	0.6170	.....	6.18	
248,000	.....	1.5400	.....	2.22	
254,000	40,000	2.3700	.....	3.15	
.....	1,000	.....	2.19	2.72	5 minutes rest given bar, at which time the bar had recovered 0.0015 in. additional. Set now being 2.0985 in. New readings taken within gauged length showing elongations after load of 40,000 lbs. per □ in. had been applied.
.....	1,000	0	.....	.....	
.....	5,000	0.0260	.....	.....	
.....	10,000	0.0575	.....	.....	
.....	15,000	0.0875	.....	.....	
.....	20,000	0.1180	.....	.....	
.....	25,000	0.1500	.....	.....	
.....	30,000	0.1830	.....	.....	
.....	1,000	.....	0.0020	.....	
285,750	45,000	3.45	.....	4.87	
317,500	50,000	4.95	.....	7.02	
.....	1,000	.....	4.60	6.44	
.....	1,000	0	.....	.....	
.....	5,000	0.0262	.....	.....	New readings taken in gauged length showing elongation after load of 50,000 lbs. per □ in. had been applied
.....	10,000	0.0585	.....	.....	
.....	15,000	0.0896	.....	.....	
.....	20,000	0.1218	.....	.....	
.....	25,000	0.1555	.....	.....	
.....	30,000	0.1896	.....	.....	
.....	1,000	.....	0.0013	.....	
349,250	55,000	.....	.....	9.72	
381,000	60,000	.....	.....	13.70	
390,000	.....	.....	.....	14.90	
400,000	.....	.....	.....	16.85	
410,000	.....	.....	.....	19.40	
412,750	65,000	.....	.....	20.30	
415,000	.....	.....	.....	21.50	
419,000	.....	.....	.....	23.37	
0	0	.....	.....	.....	Rested 5 minutes.
420,000	.....	.....	.....	23.87	
421,000	.....	.....	.....	25.15	
422,000	.....	.....	.....	25.90	
423,000	.....	.....	.....	26.70	
424,000	.....	.....	.....	27.45	
425,000	.....	.....	.....	28.40	
426,000	.....	.....	.....	29.20	
427,000	.....	.....	.....	30.18	
428,000	.....	.....	.....	30.80	
429,000	.....	.....	.....	31.45	
429,500	.....	.....	.....	32.25	
430,000	.....	.....	.....	34.30	
430,500	.....	.....	.....	35.85	Ultimate strength.
About 410,000	.....	.....	.....	36.40	Load at time of fracture.
0	0	25".20	.....	.....	15.8%.
.....	.....	.....	.....	35.37	15.9%.

Elongation of pin holes $M_1 = 0.75''$; $M_2 = 1.08''$.

Elongation of ten sections (2.79″ fractured section) 1.69″; 1.65; 1.68; 1.60; 1.91; 1.65; 1.59; 1.48; 1.51; 1.59; 1.55; 1.60; 1.60; 1.55; 1.58; 1.54; 1.50; 1.53; 1.62. Area at fracture, $5.33 \times 0.79 = 4.21$ □ in. = Reduction 33.7%. Fractured 16″ from centre of pin hole M_1. Appearance of fracture silky centre with fine granular metal at sides radiating from centre. The thickening of metal in front of pin hole M_1 and dishing of the heads was such that the under side of the head was flat after the test. Head M_2 was dished concave on the under side; placing an 18″ straight edge along the axis of the bar, showed an opening of the metal at the front side of the pin hole = 0.25″, and at the back side of the pin hole of 0.08″.

Test No. 4583. Sectional Area, 6.33 □ ″;—Gauged Length, 160″.

Loads Applied.		In Gauged Length.		Elongation.	Remarks.
Total Lbs.	Lbs. per □ in.	Elongation.	Set.	Centre to Centre of pin holes.	
6,330	1,000	0	.....	0	Short kinks in bar, near head D_2.
31,650	5,000	0.0250	.....	0.050	
63,300	10,000	0.0528	.....	0.105	
.....	1,000	.....	0.0028	0.010	
94,950	15,000	0.0800	.....	0.160	Bar 6.46″ × 0.98″.
126,600	20,000	0.1072	.....	0.210	
.....	1,000	.....	0.0039	0.020	
158,250	25,000	0.1340	.....	0.270	
.....	1,000	.....	0.0045	0.025	
160,000	.....	0.1355	.....	.....	
165,000	.....	0.1397	.....	.....	
170,000	.....	0.1440	.....	.....	
175,000	.....	0.1482	.....	.....	
180,000	.....	0.1523	.....	.....	
185,000	.....	0.1567	.....	.....	
189,900	30,000	0.1607	.....	0.32	
.....	1,000	.....	0.0050	0.04	
190,000	.....	0.1610	.....	.....	
192,000	.....	0.1630	.....	.....	
194,000	.....	0.1645	.....	.....	
196,000	.....	0.1660	.....	.....	
198,000	.....	0.1680	.....	.....	
200,000	.....	0.1695	.....	.....	
202,000	.....	0.1711	.....	.....	
204,000	.....	0.1730	.....	.....	
206,000	.....	0.1747	.....	.....	
208,000	.....	0.1766	.....	.....	
210,000	.....	0.1781	.....	.....	
212,000	.....	0.1797	.....	.....	
214,000	.....	0.1816	.....	.....	
216,000	.....	0.1831	.....	.....	
218,000	.....	0.1847	.....	.....	
220,000	.....	0.1866	.....	.....	
221,500	35,000	0.1880	.....	0.39	
.....	1,000	.....	0.0050	0.06	

Head.	Diam.	Thickness.	Diam. Pin hole.	Width back of hole.
D_1	13.95	1.08	5.02	5.62
D_2	13.97	1.02	5.02	5.62

bar 221.6 in. centre to centre of pin holes.

E = 30,270,000

Loads Applied.		In Gauged Length.		Elongation.	Remarks.
Total Lbs.	Lbs. per □ in.	Elongation.	Set.	Centre to Centre of pin holes.	
222,000	.....	0.1885	.....	.....	
224,000	.....	0.1903	.....	.....	
226,000	.....	0.1920	.....	.....	
228,000	.....	0.1936	.....	.....	
230,000	.....	0.1957	.....	.....	
232,000	36,650	0.1981	.....	.....	Elastic limit.
234,000	.....	0.2010	.....	.....	
236,000	.....	0.2047	.....	0.46	
238,000	.....	0.2092	.....	.....	
240,000	.....	0.2135	.....	.....	
242,000	.....	0.2177	.....	.....	
244,000	.....	0.2231	.....	.....	
246,000	.....	0.2307	.....	.....	
248,000	.....	0 2457	.....	.....	
250,000	.....	0.8667	.....	1.45	
253,200	40,000	2 23	.....	3.06	
.....	1,000	.....	2.02″= =1.262%	2.63	
.....	1,000	0	.....	.....	New readings taken within the gauged length, showing elongation after load of 40,000 lbs. per □″ had been applied.
.....	5,000	0 0250	.....	.....	
.....	10,000	0.0544	.....	.....	
.....	15,000	0.0835	.....	.....	
.....	20,000	0.1140	.....	.....	
.....	25,000	0.1454	.....	.....	
.....	30,000	0.1780	.....	.....	
.....	1,000	.....	0.0020	.....	
.....	45,000	3.27	.....	4.28	
.....	50,000	4.67	.....	6.54	
.....	1,000	.....	4.34= 2.712%	5.97	
.....	1,000	0	.....	.....	New readings taken within gauged length, showing elongations after loads of 50,000 lbs. per □″ had been applied.
.....	5,000	0.0256	.....	.....	
.....	10,000	0.0558	.....	.....	
.....	15,000	0.0860	.....	.....	
.....	20,000	0.1175	.....	.....	
.....	25,000	0.1500	.....	.....	
.....	30,000	0 1840	.....	.....	
.....	1,000	.....	0.0021	.....	
348,150	55,000	.....	.....	9.00	
379,800	60,000	.....	.....	12.45	
390,000	.....	.....	.....	13.75	
400,000	.....	.....	.....	15.60	
405,100	64,000	11.13=	.....	.....	Ultimate Strength.
0	0	.....	.....	15.30	6.956% 6.9%

Elongation of Pin holes $D_1 = 0.66''$; $D_2 = 0.45''$

" " 10″ Sections ;—0.70 ; 0.69 ; 0.70 ; 0.69 ; 0.71 ; 0.70 ; 0.70 ; 0.69 ; 0.69 ; 0.70 ; 0.71 ; 0.69 ; 0.69 ; 0.69 ; 0.69 ; 0.70 ; 0.69 ; 0.69 ; 0.70 ; 0.70.

Fractured suddenly without warning, under the maximum load. Broke across neck $6\frac{1}{2}''$ from centre of pin hole D_1. Line of fracture $8\frac{1}{4}''$ long. Appearances granular, radiating from a small fire

crack 0.30″ long by 0.05″ deep and a dull spongy spot 0.4″ × 0.3″; surface of fracture serrated in radiating lines. It is probable the fracture began at the fire-crack corner and tore across the neck. Evidence of this manner of fracture is furnished by the marks near the middle of the fractured surface of the long end of the bar, made by blows on the corner of fracture opposite side with fire crack, of head D_1, during recoil after fracture, the head swinging around.

Test No. 4583A.

Bar D_1 D_2 rested five days between tests No. 4583 and 4583A.

End D_2, secured by its pin.

" D_1, " between flat steel dies.

Gauged length same as in experiment No. 4583, covering 160″ of original length. Actual present length 171.13″.

Load Applied.		In Gauged Length.		Elongation.	Remarks.
Total Lbs.	Lbs. per □″	Elongation.	Set.	Centre to Centre of pins.	
6,330	1,000	0	0	.....	
31,650	5,000	0.0258	.....	.....	
63,300	10,000	0.0573	.....	.....	
94,950	15,000	0.0884	.....	.....	
126,600	20,000	0.1192	.....	.....	
158,250	25,000	0.1503	.....	.....	
189,900	30,000	0.1815	.....	.....	
6,330	1,000	.....	0.0008	.....	
189,900	30,000	0.1817	.....	.....	
6,330	1,000	.....	0.0010	.....	
221,550	35,000	0.2128	.....	.....	
253,200	40,000	0.2440	.....	.....	
284,850	45,000	0.2750	.....	.....	
316,500	50,000	0.3065	.....	.....	
6,330	1,000	.....	0.0016	.....	
31,650	5,000	0.0268	.....	.....	
63,300	10,000	0.0580	.....	.....	
94,950	15,000	0.0890	.....	.....	
126,600	20,000	0.1200	.....	.....	
158,250	25,000	0.1510	.....	.....	
189,900	30,000	0.1820	.....	.....	
6,330	1,000	.....	0.0013	.....	
430,000	.....	.....	.....	.....	Rapid stretching began.
453,000	71,560	.....	.....	.....	Ultimate strength.
0	0	13.77″ =		8.6 %	

Total elongation of pin hole D_2 = 0.58″.

Total " of 10″ sections: two sections at end D_1 not measured, covered by holder dies; 0.69; 0.69; 0.70; 0.70; 0.70; 0.84; 0.88; 0.90; 0.94; 0.91; 0.92; 0.92; 0.94; 1.00; 1.00; 1.04; 1.30 (2.55″ fractured section).

Area at fracture 5.29″ × 0.76 = 4.02 □″. Contraction = 36.5%.

Fractured 19½″ from center of pin hole D_2. Appearance fine silky with about 10% granular metal at one edge, radiating from center.

Test No. 4583B.

Bar rested two hours between tests No. 4583A and No. 4583B.

Both ends of bar secured between flat steel dies.

Rapid stretching began at 445,000 lbs. tension.

Ultimate strength 456,100 lbs. = 72,050 lbs. per □″.

Load at time of fracture 415,000 lbs.

Total elongation of 10″ sections: First section at end of D_1 not measured; covered by holder dies (3.05″ fractured section), 1.69; 1.50; 1.41; 1.20; 1.22; 1.13; 1.10; 1.15; 1.25; 1.16; 1.11; 1.11; 1.18.

Area of fracture 5.2″ × 0.75″ = 3.9 □″. Contraction of area = 38.4%.

Fractured 25″ from first fracture, or 31½″ from center of pin hole D_1. Appearance fine silky with trace of granulation along middle of fractured surface.

Test No. 4584.

Sectional area = 6.33 □″; *gauged length* = 20″.

Loads Applied.		In Gauged Length.		Elongation.	Remarks.				
Total Lbs.	Lbs. per □ inch.	Elongation.	Set.	Centre to Centre of pins.					
6,330	1,000	0	.....	0	Bar 6.46″ × 98″.				
31,650	5,000	0.0388	.....	0.06					
63,300	10,000	0.0770	.....	0.12	Head.	Diam.	Thickness.	Diam. pin hole.	Width back of hole.
.....	1,000	.....	0.043	0.015					
94,950	15,000	0.1123	.....	0.180					
126,600	20,000	0.1470	.....	0.24	Z_1	14.00″	1.04	5.02	5.55
.....	1,000	.....	0.0059	0.02	Z_2	14.00	1.04	5.02	5.63
158,250	25,000	0.1810	.....	0.30	Bar 262.70″ c. to c. of pin holes.				
.....	1,000	.....	0.0067	0.025					
160,000	.....	0.1830	.....	.....					
165,000	.....	0.1881	.....	.....					
170,000	.....	0.1935	.....	.....					
175,000	.....	0.1995	.....	.....					
180,000	.....	0.2045	.....	.....					
185,000	.....	0.2096	.....	.....					
189,900	30,000	0.2150	.....	0.365	E 29,630,000.				
.....	1,000	.....	0.0072	0.04					
190,000	.....	0.2150	.....	.....					
192,000	.....	0.2170	.....	.....					
194,000	.....	0.2194	.....	.....					
196,000	.....	0.2213	.....	.....					
198,000	.....	0.2235	.....	.....					

Loads Applied.		In Gauged Length.		Elongation.	Remarks.
Total Lbs.	Lbs. per □ inch.	Elongation.	Set.	Centre to Centre of Pins.	
200,000	.....	0.2256	.....	.....	
202,000	.....	0.2280	.....	.....	
204,000	.....	0.2300	.....	.....	
206,000	.....	0.2322	.....	.....	
208,000	.....	0.2343	.....	.....	
210,000	.....	0.2365	.....	.....	
212,000	.....	0.2390	.....	.....	
214,000	.....	0.2409	.....	.....	
216,000	.....	0.2430	.....	.....	
218,000	.....	0.2452	.....	.....	
220,000	.....	0.2474	.....	.....	
221,550	35,000	0.2490	.....	0.44	
.....	1,000	.....	0.0104	0.05	
222,000	.....	0.2500	.....	.....	
224,000	.....	0.2520	.....	.....	
226,000	.....	0.2545	.....	.....	
228,000	.....	0.2566	.....	.....	
230,000	.....	0.2590	.....	.....	
232,000	.....	0.2617	.....	.....	
234,000	.....	0.2644	.....	.....	
236,000	.....	0.2670	.....	.....	
238,090	37,600	0.2703	.....	.....	Elastic Limit.
240,000	.....	0.2732	.....	.....	
242,000	.....	0.2783	.....	0.64	Rapid stretch taking place in stem 20″ from centre of pins.
244,000	.....	0.2860	.....	0.74	
246,000	.....	0.3150	.....	0.88	
248,000	.....	0.4910	.....	1.16	
250,000	.....	1.1000	.....	1.78	
253,200	40,000	1.92	.....	2.66	
284,850	45,000	3.91	.....	5.14	
316,500	50,000	5.55	.....	7.38	
348,150	55,000	.....	.....	10.20	
379,800	60,000	.....	.....	14.20	
411,450	65,000	.....	.....	20.40	
419,000	.....	.....	.....	22.82	
0	0	.....	.....	.....	Rested 5 minutes.
420,000	.....	.....	.....	24.30	
422,000	.....	.....	.....	25.24	
424,000	.....	.....	.....	26.17	
426,000	.....	.....	.....	27.10	
428,000	.....	.....	.....	28.30	
430,000	.....	.....	.....	29.25	
432,000	.....	.....	.....	30.50	
434,000	.....	.....	.....	32.10	
435,000	68,720	.....	.....	33.90	Ultimate strength.
414,000	.....	.....	.....	34.50	Load at time of fracture.
0	0	24.67″ =			12.3 %
				33.18 =	12.6 %

Elongation of pin holes $Z_1 = 0.65''$; $Z_2 = 0.73.''$ Elongation of 10″ sections : 1.38 ; 1.28 ; 1.25 ; 1.26 ; 1.22 ; 1.22 ; 1.20 ; 1.20 ; 1.21 ; 1.22 ; 1.19 ; 1.26 ; 1.34 ; 1.21 ; 1.20 ; 1.19 ; 1.12 ; 1.15 ; 1.20 ; 1.21 ; 1.32 ; 1.50 ; 1.62 ; (2.50 fractured section).

Area at fracture $5.34'' \times 0.78'' = 4.17$ □″. Contraction of area, 34.1 %.

Fractured 19″ from centre of pin hole Z_2. Appearance of fracture silky 70%, with fine granular metal 30% at sides radiating from centre.

Test No. 4585.

Sectional area = 6.20 □″; *gauged length* 200″.

Loads Applied.		In Gauged Length.		Elongation.	Remarks.
Total Lbs.	Lbs. per □ in.	Elongation.	Set.	Centre to Centre of Pins.	
6,200	1,000	0	.....	0	
31,000	5,000	0.037	.....	0.07	Bar 6.46″ × 0.96″
62,000	10,000	0.0724	.....	0.13	
.....	1,000	.....	0.0069	0.02	Head. Diam. Thickness. Diam. of pin-hole. Width back of hole.
93,000	15,000	0.1056	.....	0.19	
124,000	20,000	0.1394	.....	0.25	
.....	1,000	.....	0.0074	0.025	P_1 13.90 1.02 5.02 5.60
155,000	25,000	0.1725	.....	0.31	P_2 14.05 1.03 5.02 5.70
.....	1,000	.....	0.0070	0.03	
160,000	.....	0.1780	.....	.....	Bar 261.85″ c. to c. of pin holes.
165,000	.....	0.1834	.....	.....	
170,000	.....	0.1887	.....	.....	
175,000	.....	0.1940	.....	.....	
180,000	.....	0.2000	.....	.....	
185,000	.....	0.2047	.....	.....	
186,000	30,000	0.2060	.....	0.37	E = 29,960,000.
.....	1,000	.....	0.0070	0.045	
188,000	.....	0.2085	.....	.....	
190,000	.....	0.2102	.....	.....	
192,000	.....	0.2128	.....	.....	
194,000	.....	0.2147	.....	.....	
196,000	.....	0.2167	.....	.....	
198,000	.....	0.2190	.....	.....	
200,000	.....	0.2210	.....	0.40	
202,000	.....	0.2233	.....	.....	
204,000	.....	0.2255	.....	.....	
206,000	.....	0.2275	.....	.....	
208,000	.....	0.2300	.....	.....	
210,000	.....	0.2320	.....	.....	
212,000	.....	0.2340	.....	.....	
214,000	.....	0.2363	.....	.....	
216,000	.....	0.2387	.....	.....	
217,000	35,000	0.2404	.....	0.45	
.....	1,000	.....	0.0065	0.07	
218,000	.....	0.2419	.....	.....	
220,000	.....	0.2445	.....	.....	
222,000	35,810	0.2474	.....	0.465	Elastic limit.
224,000	.....	0.2521	.....	.....	
226,000	.....	0.2595	.....	.....	
228,000	.....	0.2850	.....	.....	
230,000	.....	0.3635	.....	0.61	
232,000	.....	0.3781	.....	0.69	
234,000	.....	0.3907	.....	0.81	
236,000	.....	0.4080	.....	0.93	

Loads Applied.		In Gauged Length.		Elongation.	Remarks.
Total Lbs.	Lbs. per □ in.	Elongation.	Set.	Centre to Centre of Pin Holes.	
238,000	.....	1.35	.....	1.99	
240,000	.....	1.87	.....	2.50	
248,000	40,000	2.80	.....	3.57	
279,000	45,000	4.36	.....	5.64	
310,000	50,000	6.25	.....	8.14	
341,000	55,000	.....	.....	11.35	
372,600	60,000	.....	.....	16.10	
397,000	.....	.....	.....	22.70	
0	0	.....	.....	.....	
400,000	.....	.....	.....	24.30	
0	0	.....	.....	.....	Rested 5 minutes.
400,000	.....	.....	.....	24.30	
403,000	65,000	.....	.....	25.90	
405,000	.....	.....	.....	27.20	
408,000	.....	.....	.....	30.40	Ultimate strength.
375,000	.....	.....	.....	31.20	Load at time of fracture.
0	0	24.05	.....	.....	= 12.0%.
.....	.....	.....	.....	30.21	= 11.5%.

Elongation of pin-holes, $P_1 = 0.68''$; $P_2 = 0.064''$; elongation of 10″ sections: 1.01; 0.99; 1.00; 1.00; 1.00; 0.99; 0.99; 1.04; 1.05; 1.03; 1.04; 1.25; 1.44; 1.15; 1.00; 1.02; 1.08; 1.01; 1.00; 1.08; 1.38; (3.50″ fractured section); 1.48; 1.10.

Area at fracture, $5.10'' \times 0.74'' = 3.77\ \square''$; contraction of area, 39.2%.

Fractured $42\frac{3}{4}$ in. from centre of pin-hole P_2.

Tore apart from one edge; fractured ends brought together, leave an opening on this edge of 0.15″; short surface cracks and blister $1\frac{1}{4}'' \times \frac{3}{8}''$ near edge first fractured.

Appearance, fine silky 70%, fine granular 30%, radiating from centre, for the part last fractured.

Heads were dish-shaped after fracture; edge of pole nearest end of bar raised 0.15″ above 18 in. straight edge, other edge of hole raised 0.05″.

Test No. 4586.

Sectional area = 6.26 □″ ; *gauged length*, 200″.

Loads Applied.		In Gauged Length.		Elongations.	Remarks.
Total Lbs.	Lbs. per □ in.	Elongation.	Set.	Centre to Centre of Pin Holes.	
6,260	1,000	0	.....	0	Bar 6.45″ × 0.97″
31,300	5,000	0.0400	.....	0.08	
62,600	10,000	0.0748	.....	0.14	
.....	1,000	.....	0.0091	0.02	
93,900	15,000	0.1086	.....	0.20	
125,200	20,000	0.1420	.....	0.27	
.....	1,000	.....	0.0093	0.030	
156,500	25,000	0.1755	.....	0.32	
.....	1,000	.....	0.0104	0.03	Bar 262.12″ centre to centre of pin holes.
.....	1,000	.....	.....	.....	
.....	5,000	0.0393	.....	.....	
.....	10,000	0.0740	.....	.....	Readings taken after fifteen hours rest introduces these figures.
.....	15,000	0.1080	.....	.....	
.....	20,000	0.1414	.....	.....	
.....	25,000	0.1745	.....	.....	
.....	1,000	.....	0.0079	.....	
160,000	.....	.....	.....	.....	
165,000	.....	.....	.....	.....	
170,000	.....	.....	.....	.....	
175,000	.....	.....	.....	.....	
180,000	.....	.....	.....	.....	
185,000	.....	.....	.....	.....	
187,800	30,000	.....	.....	0.380	E = 29,670,000.
.....	1,000	.....	0.0075	0.045	
190,000	.....	0.2105	.....	.....	
192,000	.....	0.2128	.....	.....	
194,000	.....	0.2153	.....	.....	
196,000	.....	0.2175	.....	.....	
198,000	.....	0.2200	.....	.....	
200,000	.....	0.2222	.....	0.41	
202,000	.....	0.2250	.....	.....	
204,000	.....	0.2280	.....	.....	
206,000	.....	0.2312	.....	.....	
208,000	33,230	0.2343	.....	.....	Elastic limit.
210,000	.....	0.2390	.....	0.45	
212,000	.....	0.2435	.....	.....	
214,000	.....	0.2476	.....	.....	
216,000	.....	0.2530	.....	.....	
218,000	.....	0.2650	.....	.....	
219,600	35,000	0.3094	.....	0.55	
.....	1,000	.....	0.0810	0.175	
220,000	.....	0.6965	.....	0.98	
222,000	.....	1.32	.....	1.66	
225,360	36,000	1.64	.....	2.07	
231,620	37,000	2.16	.....	2.75	
237,880	38,000	3.08	.....	3.77	
244,140	39,000	3.33	.....	4.21	
250,400	40,000	3.58	.....	4.56	
281,700	45,000	5.33	.....	6.92	

Head.	Diam.	Thickness.	Diam. of pin-hole.	Width back of hole.
U_1	13.90	1.02	5.02	5.60
U_2	13.80	1.04	5.02	5.55

Loads Applied.		In Gauged Length.		Elongation.	Remarks.
Total Lbs.	Lbs. per □ in.	Elongation.	Set.	Centre to Centre of Pins.	
313,000	50,000	7.50	.....	9.75	
344,300	55,000	.....	.....	13.60	
375,600	60,000	.....	.....	20.63	
0	0	.....	.....	.....	Rested 5 minutes.
380,000	.....	.....	.....	21.94	
385,000	.....	.....	.....	23.70	
390,000	.....	.....	.....	25.94	
395,000	.....	.....	.....	28.05	
400,000	.....	.....	.....	31.20	
401,000	.....	.....	.....	32.30	
402,000	.....	.....	.....	34.10	
402,600	.....	.....	.....	35.10	
403,000	.....	.....	.....	36.60	
403,200	64,410	.....	.....	38.25	Ultimate strength.
355,000	.....	.....	.....	40.65	Load at time of fracture.
0	0	32.84″	.....	.....	= 16.4%.
.....	.....	.....	.....	39.56	= 15.1%.

Elongation of pin-holes, $U_1 = 0.70''$; $U_2 = 0.75''$.

Elongations of 10″ sections: 1.39; 1.42; 1.81; 1.79; 1.75; 1.31; 1.62; 1.89; 1.29; 1.12; 1.19; 2.05; 1.90; 1.32; 1.10; 1.45; 1.60; 1.50; 1.19; 1.14; 2.24; (3.58″; fractured section); 1.30; 1.10″.

Area at fracture 4.94″ × 0.64″ = 3.16 □″.

Contraction of area = 49.5%.

Fractured 46½″ from centre of pin-hole U_2.

Appearance, fine silky 100%; opened a seam ⅝″ long near centre of fracture. Heads dished about .08″ concave, measured from an 18″ straight edge.

Test No. 4587.

Sectional area = 6.27 □″; *gauged length* 200″.

Loads Applied.		In Gauged Length.		Elongation.	Remarks.
Total Lbs.	Lbs. per □ in.	Elongation.	Set.	Centre to Centre of Pins.	
6,270	1,000	0	.....	0	Bar 6.46″ × 0.97″
31,350	5,000	0.0341	.....	0.06	
62,700	10,000	0.0690	.....	0.12	
.....	1,000	.....	0.0045	0.01	
94,050	15,000	0.1025	.....	0.18	
125,400	20,000	0.1365	.....	0.24	
.....	1,000	.....	0.0050	0.015	
156,750	25,000	0.1700	.....	0.31	
.....	1,000	.....	0.0050	0.025	
160,000	.....	0.1733	.....	.....	

Head.	Diam.	Thickness.	Diam. of pin-hole.	Width back of hole.
L_1	13.65	1.02	5.02	5.55
L_2	14.00	1.03	5.02	5.65

Bar 261.72″ long c. to c. of pin-holes.

Loads Applied.		In Gauged Length.		Elongation.	Remarks.
Total Lbs.	Lbs. per □ in.	Elongation.	Set.	Centre to Centre of of Pins.	
165,000	.....	0.1784	.....	.....	
170,000	.....	0.1836	.....	.....	
175,000	.....	0.1889	.....	.....	
180,000	.....	0.1945	.....	.....	
185,000	.....	0.1998	.....	.....	
188,100	30,000	0.2030	.....	0.37	
.....	1,000	.....	0.0053	0.03	$E = 29{,}960{,}000$.
190,000	.....	0.2050	.....	.....	
192,000	.....	0.2076	.....	.....	
194,000	.....	0.2095	.....	.....	
196,000	.....	0.2115	.....	.....	
198,000	.....	0.2138	.....	.....	
200,000	.....	0.2160	.....	0.39	
202,000	.....	0.2180	.....	.....	
204,000	.....	0.2200	.....	.....	
206,000	.....	0.2223	.....	.....	
208,000	.....	0.2248	.....	.....	
210,000	.....	0.2265	.....	.....	
212,000	.....	0.2287	.....	.....	
214,000	.....	0.2310	.....	.....	
216,000	.....	0.2330	.....	.....	
218,000	.....	0.2353	.....	.....	
219,450	35,000	0.2368	.....	0.44	
.....	1,000	.....	0.0046	0.06	
220,000	.....	0.2375	.....	.....	
222,000	.....	0.2400	.....	.....	
224,000	.....	0.2420	.....	.....	
226,000	.....	0.2443	.....	0.47	
228,000	.....	0.2470	.....	0.49	
230,000	.....	0.2500	.....	0.505	
232,000	.....	0.2524	.....	0.51	
234,000	.....	0.2553	.....	.....	
236,000	.....	0.2580	.....	0.535	Elastic limit.
238,000	.....	0.2618	.....	0.55	
240,000	.....	0.2675	.....	0.58	
242,000	.....	0.2736	.....	0.61	
244,000	.....	0.9800	.....	1.60	
246,000	.....	1.28	.....	1.96	
250,800	40,000	2.31	.....	3.06	
282,150	45,000	4.00	.....	5.21	
313,500	50,000	5.75	.....	7.56	
344,850	55,000	.....	.....	10.30	
376,200	60,000	.....	.....	14.70	
390,000	.....	.....	.....	17.00	
400,000	.....	.....	.....	19.50	
410,000	.....	.....	.....	22.65	
0	0	.....	.....	.....	
420,000	.....	.....	.....	27.00	
425,000	.....	.....	.....	30.45	
426,000	.....	.....	.....	31.70	
427,000	.....	.....	.....	32.90	
428,000	.....	.....	.....	34.50	
428,200	69,290	.....	.....	35.45	Ultimate strength.
380,000	.....	.....	.....	36.10	Approximate load at time of fracture.
0	0	27.79″	.....	.....	= 13.9%.
.....	.....	.....	.....	35.23	= 13.5%.

Elongation of pin-holes $L_1 = 0.80''$; $L_2 = 0.58$.

Elongation of 10″ sections:—1″.53; 1.25; 1.40; 1.43; 1.31; 1.31; 1.28; 1.25; 1.26; 1.21; 1.28; 1.45; 1.52; 1.21; 1.15; 1.15; 1.11; 1.10; 1.05; 1.12; 1.50; (3.70″ fractured section) 1.64; 1.25.

Area at fracture $5.02'' \times 0.72'' = 3.61 \square''$; contraction of area $= 42.4\%$.

Fractured 43″ from centre of pin-hole L_2; appearance, fine silky with slight granulations.

F. H. Parker,
Major of Ordnance, Commanding.

Correct: I. E. Howard.

DISCUSSION.

The President.—Discussion on this paper is in order. The Chair will remark that the subject discussed by Mr. Henning is one of very great importance. It was his pleasure to be present during the experiments on the Keystone eye-bars that he speaks of, and the results obtained there were regarded by himself and by all others who were familiar with them as extraordinary. He is very much pleased to know that Mr. Henning is able to give them to the Society.

In regard to punching steel, I have recently been making some experiments at Watertown, and this matter of the relative values of drilled and punched holes I propose to investigate fully, as far as boiler work is concerned.

Mr. Henning speaks of welded eye-bars. We have found that it was possible, in the construction of boilers, to make man-hole nozzles of three-quarter-inch steel. These nozzles which are some eighteen inches in diameter as arranged for a seven-foot boiler, can be welded perfectly, and flanged out so as to make a perfect top flange, with the bottom flange curved to suit the boiler.

Mr. Henning.—Those flanges are about an inch and three-quarters or two inches wide, are they not?

The President.—About two inches and a half wide, and some three inches wide. I have used steel made by the Cleveland Steel Company, by Naylor & Co., and by the Nashua Iron & Steel Company, and I have no doubt that the steel made by Mr. Wellman will do the same thing. We have not had the pleasure of trying that yet—and we have not had any difficulty whatever in man-holes for boilers, tested with 225 pounds cold pressure.

Mr. Henning.—The Continental Iron Works, in Brooklyn, weld all the government torpedoes, which are about twenty-eight inches in diameter, and flanged all around. They could never do it satisfactorily with iron; they do it with steel easily.

The President.—We also have welded the butt straps surrounding the boiler for the external seams, which are some eight and a half inches wide and seven feet in diameter. Those have always given good results. And the success attending the welding of those butt straps suggested to the Chair that it was possible to make a boiler with all the horizontal seams welded, making them in telescopic form, from four to six feet wide. I believe that is entirely practical, if anybody is willing to pay for it.

Mr. Henning.—The Continental Iron Works are doing it now, and with great success.

Mr. Le Van.—The gentleman stated in his paper that the difference between punched holes and drilled holes was in favor of the drilled holes. Did he have reference to boiler plates?

Mr. Henning.—As to the cost of punching and drilling?

Mr. Le Van.—Yes, sir.

Mr. Henning.—It depends, probably, somewhat upon the thickness of the plate; but, as a rule, in boiler work—say in a $\frac{3}{8}$-inch plate—it would probably be better to drill after the plates are matched and bolted in place, for several practical reasons. First, the holes must be perfectly true, and about the only way to get them true is to put the rims together and drill them true in place. If it is done otherwise and you leave one hole which is but partially reamed, your plate in riveting up is very likely to split right there, should the rough edge of the hole be nearest the edge of the plate. That is the trouble in boiler plates, which would be different from bridge work, where your material is almost always straight; in the best designs bent or curved detail is always avoided, as with a little thought straight short pieces can be employed to advantage.

Mr. Le Van.—I would state that the Baldwin Locomotive Works, of Philadelphia, have just finished three steel boilers for a client of mine, in which the holes were first punched and afterward reamed to receive the rivets. In the four previous boilers built to my order, the holes were drilled in the sheet, and we found that with the greatest care we could not make the holes match. As a consequence, the holes had to be reamed and a rivet of larger size used. Therefore, in the last three boilers we concluded we would

punch all the holes an eighth of an inch less in diameter than the size of the rivet to be used, and then all plates were brought well together in place, and the holes were reamed out to the proper size. We found by comparing the cost with that of the drilled plates that we made a difference of twenty per cent. in favor of the punched holes reamed. From the above we found that punched holes in steel plates of a smaller diameter than the rivets and reamed will be cheaper and better than drilled holes, as the reaming removes the upsetting and hardening around the edge of the holes, due to the punching of steel. Iron plate that is not improved by punching is not a proper material to enter into boiler construction.

Mr. Henning.—When I speak of drilled holes I do not refer to holes drilled in each piece separately and then put together because it is almost impossible to get the holes to match when you superimpose one on the other. We hold the plates together, with bolts not more than fifteen inches apart, and often less, and the plates are so straight and flat that there is no space between them; we cannot get a knife edge or a sheet of paper between the plates, all pieces having been straightened hot before assembling. We ream out or countersink the top and bottom edges of each hole so as to form a fillet under the heads of the rivets. We have found that to be absolutely necessary. Without that I know that more than eighty per cent. of the rivets are not perfectly tight; but with this filleting I have not found one-half per cent. of rivets not perfectly tight.

Mr. Le Van.—You have reference not to boiler work, but to bridge work?

Mr. Henning.—To bridge work; yes, sir.

Mr. Le Van.—I am speaking of boiler work.

Mr. Henning.—The quality of boilers generally depends on how closely plates are packed together. I built several dozen boilers myself some time ago, and I know that I would generally get a tight job if I first saw that the plates were fitted perfectly, so that you could not get anything between. But if you allow the plates to be loose so that you can get anything between, it is utterly useless to try to do anything with them, because you cannot get the rivets down. The only way to get a tight job then is to calk the end, and the calking on the joint around a boiler is merely an additional safeguard. It ought never to be done to get a tight job. The boiler ought to be tight without that calking—the best work will have it that way. (Applause.)

The President.—The Chair will remark, in closing this discussion, that in investigating the matter of drilled *versus* punched holes for a large boiler which he had occasion to construct recently he decided, after reading the reports of the committee appointed by the Institution of Mechanical Engineers of Great Britain, that the punched hole reamed out for boiler work was superior to others; but we made a proviso in each contract that the holes in the plates should be countersunk nearly $\frac{1}{16}$ of an inch on each side, the plates being $\frac{9}{16}$ thick, with rivets $\frac{15}{16}$ in diameter. In testing riveted joints it is impossible to get an accurate idea of the strain that is produced in actual work under steam—from a tensional machine—for the simple reason that the plate is pulled only in the direction of its length, while in the curved plates of the boiler, the strain is the resultant of numerous radial forces, or, to speak more correctly, of pressure acting radially in different directions.

A transverse strain is put upon the riveted specimen when pulled in a tensional machine by the buckling of the outer plates.

A seam that would show a beautiful silky fracture in simple tension, when exposed to transverse strain shows a granular fracture, and that is a peculiarity of steel which has led a great many engineers to think that it was an unsafe material to be used. In a pair of boilers which were made for the city of Boston, for their improved sewerage work, a coupon strip was cut from every plate that was used in the boiler, and I think there were about four plates made for every one that was accepted. We found plates that were apparently made from the same heat that showed, some of them, a granular fracture, and others a beautiful silky fracture. The requirement was 37,000 pounds elastic limit, the ultimate strength not exceeding sixty-five nor less than sixty thousand pounds; and you can see it was necessary to condemn about three plates out of four to get it. The steel was Open Hearth. The parties supposed I had set up a job for somebody else, because of such a hard condition.

Mr. Le Van.—In the last boilers I spoke of, we had coupon strips to accompany each plate. The tensile strength was not to be less than 55,000 nor exceed 60,000 pounds, and have an elongation of 30 per cent. in a section originally twelve thicknesses of the plate. The Otis Steel Company, of Cleveland, furnished the steel, and all the plates came up to the specifications in every respect; there was no plate condemned.

The President.—This was a general specification. We issued

this specification and received bids for the boilers. There was no special brand of steel required. It was open to all bidders. The parties who bid for the boilers supplied their own steel. And I will mention as an incident that the City Engineer of Boston became discouraged after we had condemned a lot of plates, and he got plates from another works who were sure they could furnish material of that kind every time. But they failed to come up to the standard.

I will also state a matter that will be of interest. Mr. Kendall, of Kendall & Roberts, Cambridgeport, told me that of several thousand boilers built of steel, they had never had one fail or give any trouble.

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